# SCIENTIFIC FARM ANIMAL PRODUCTION

**Abridged Edition**

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# Scientific Farm Animal Production

**Abridged edition**


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# Contents

# 1. Livestock and World Needs

What part and how much of a part do our farm animals play in meeting our world's needs? Our world is often described as a hungry world. What can be done to alleviate the suffering and to prevent or at least minimize suffering in the future?

Machines for power find great use in the industrial nations, but throughout vast areas men, women, children (Figure 1-1), and animals pull the plows, pump the water, carry goods and transport people, grind the grain, and guide the blind. Machines even today play a relatively minor role worldwide.

Animals, notably horses and mules, cattle, and water buffaloes (Figure 1-2), are used for work on farms. Donkeys, horses, camels, llamas, and yaks are pack animals used for freighting a great variety of commodities long and short distances (Figure 1-3). Dogs are worked for herding sheep and cattle. They are trained to protect people, and, in police work, to follow scent and attack. Trained dogs are excellent as guides for blind persons (Figure 1-4). Some animals are kept primarily for pleasure, notably racehorses, riding horses, dogs, and cats. Sheep and goats grow fiber (wool and mohair) that is important in world trade. The hides of some animals have value when processed into leather. Pharmaceuticals are important products coming from modern-day slaughterhouses.

Besides all these various contributions made by animals, the great benefit to mankind comes from the food they yield in meat, milk, and eggs.

This chapter was written by Dr. Fred F. McKenzie specially for this book.

**FIGURE 1-1.** *Men and women carry great loads. This is an everyday occurrence in vast areas of the world today. Here, the man's load is firewood for the ovens in Ife, Nigeria. The women, young and old, are transporting palm wine from the tropical forest to the village for sale in the Western State of Nigeria.*

**FIGURE 1-2.** *Water buffaloes are used to cultivate flooded rice paddies in West Java, Indonesia. In addition to their value as draft animals, water buffaloes are often used as an investment—many Javanese farmers prefer investing in water buffaloes to depositing money in a bank. Courtesy of Dr. Budi S. Nara.*

**FIGURE 1-3.** *The donkey is used a great deal in Turkey. Many donkeys are ridden, but most carry packs. This one carries cans of milk and the vendor himself as the vendor travels his regular route in the city of Izmir, selling milk from door to door.*

**FIGURE 1-4.** *The dog serves man in a variety of ways. This Labrador retriever guide dog leads the way for a Californian. Courtesy of Guide Dogs for the Blind, San Rafael, California.*

Hunger, real and extensive, is brought on by scarcity of food, but *malnutrition* is a more descriptive term of the condition that results from an inadequate diet because it conveys the idea of imbalance of, or even deficiency of, essential elements in the diet as well as an insufficient food intake.

The invention and marketing of conveniences and machines in the "developed" countries (such as Canada, the United States, and Japan) generally require a considerable outlay of capital. Where capital is lacking, much of the population is rural and is engaged in producing food. In Indonesia, for example, more than 80% of the people are agriculturists. Indonesia and similar countries are called "undeveloped" or "developing" nations.

The essential components of one's diet are energy, high-quality protein, vitamins, and minerals. Hunger and malnutrition are brought about by insufficiency in one or more of these essentials, or by imbalances. Therefore, the quantity and availability of grain, roots, tubers, vegetables, fruits, and animal products are important. Scarcity is brought about by poor crops, lack of capital to purchase, and poor distribution, all of which have a great variety of causes. The world demand for food today is greater than ever before, chiefly because there are more people than ever and the population is rising sharply. The 1970 world population stood at 3,632,000,000. The 1985 figure is projected to be 4,933,000,000. By A.D. 2000 we can expect, as a "low variant" estimate, 5,977,000,000 people in this world (Carter, 1974).

Table 1-1 shows the world inventory of livestock, milk, poultry, and eggs, what the recent trends in production of these items are, and how much production and demand are anticipated in 1985. Despite the anticipated significant increase in food production by 1985 over the current level, it appears that demand for beef, mutton, and milk will exceed the supply. However, the estimated production of pork, poultry meat, and eggs may exceed the anticipated demand.

For the average world citizen, cereals provide 52.4% of the calories and 47.4% of the daily protein intake. Animal products, including fats, provide 16.7% of the total calories and 31.7% of the protein. The remaining nutrients are from roots, tubers, sugar and sugar products, pulses, nuts and oilseeds, vegetables, and fruits (Carter, 1974).

The anticipated amounts of food needed to meet the demand in the years ahead are given in Table 1-2. One can see what increases will be

**Table 1-1. World inventory of livestock, milk, poultry, and eggs projected to 1985, food production from this inventory projected to 1985, and estimated demand in 1985.**

| | *Inventory* | | | | *Production* | | *Estimated demand* |
|---|---|---|---|---|---|---|---|
| | *1950* | *1960* | *1970* | *1985* | *1970* | *1985* | *1985* |
| | *Numbers (millions)* | | | | *Metric tons (millions)* | | |
| Cattle | 763.3 | 920.6 | 1250.7 | 1936.8 | 40.29 | 58.06 | 60.18 |
| Sheep and goats | 1012.0 | 1218.7 | 1457.3 | 2155.7 | 7.09 | 10.27 | 11.35 |
| Swine | 227.7 | 343.1 | 626.9 | 1075.4 | 37.14 | 54.22 | 50.81 |
| Poultry | — | — | 5560.2 | 9668.7 | 17.67 | 30.41 | 28.12 |
| Milk equivalent | — | — | — | — | 398.50 | 511.67 | 565.86 |
| Eggs | — | — | — | — | 17.68 | 36.13 | 27.13 |

Source: Carter, H. O., ed. *A Hungry World: The Challenge to Agriculture.* Davis: University of California Division of Agricultural Sciences. Copyright© 1974.

Table 1-2. **World demand for various foods in 1970, with demand estimated for the years 1985 and 2000 (in millions of metric tons).**

| *Food* | *1970* | *1985* | *2000* |
|---|---|---|---|
| Meat | 105.7 | 164.8 | 216.9 |
| Milk | 380.6 | 543.6 | 715.6 |
| Eggs | 18.2 | 27.1 | 35.7 |
| Fish | 42.9 | 69.1 | 90.9 |
| Fats and oils | 30.5 | 44.9 | 59.1 |
| Wheat | 161.6 | 210.6 | 277.3 |
| Rice | 175.1 | 257.0 | 338.3 |
| Coarse grains | 129.3 | 177.6 | 233.8 |
| Roots, tubers | 275.3 | 353.7 | 465.6 |
| Sugar products | 80.6 | 122.3 | 161.1 |
| Pulses, nuts | 38.9 | 59.2 | 77.9 |
| Oil seeds | 12.7 | 18.3 | 24.0 |
| Vegetables | 220.5 | 327.6 | 431.2 |
| Fruits | 142.9 | 231.4 | 304.6 |

Source: Carter, H. O., ed. *A Hungry World: The Challenge to Agriculture.* Davis: University of California Division of Agricultural Sciences. Copyright© 1974.

necessary by comparing the anticipated amounts needed with the demand shown for 1970. The demand shown for the year 2000 is a medium estimate; the need might be higher or, perhaps, somewhat less. The estimated total human demand for meat for the year 2000 is derived by anticipating an annual 3.0% to 4.1% increase in demand starting with 1970.

The amount of food consumed per person in 1970 and estimates of the amount that each person will consume in 1985 and 2000 are shown in Figure 1-5. The top graph shows the average food consumption per person per year for the world as a whole and the bottom graph shows the average amount of food consumed per person per year in certain regions of the globe.

Much of the malnutrition that exists in all parts of the world is due to the lack of high-quality protein that is found in milk, meat, eggs, and fish. This situation emphasizes the urgency of increasing livestock production everywhere in order to meet the needs of the expanding human population, which is not yet under any meaningful control in most areas of the world.

Why is animal protein more effective for nourishing the body than protein from other sources? Proteins differ in quality chiefly because they vary in the relative amount of amino acids present (amino acids are molecules that are the basic constituents of proteins). Food of animal origin is relatively rich in the amino acid lysine, which is essential to growth in humans. Cereals are much lower in lysine. Furthermore, diets of quality are more readily balanced and made more appetizing when foods of animal origin are included.

The amino acids that are essential to the human are: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Cystine can provide some methionine and tyrosine can provide some phenylalanine.

Table 1-3 gives the amounts of the amino acids, in milligrams (mg) per gram (g) of protein, found in various food sources. Cereals provide 20.8 mg of lysine per g of protein; legumes, 62.4; meat, 81.6; eggs, 67.2;

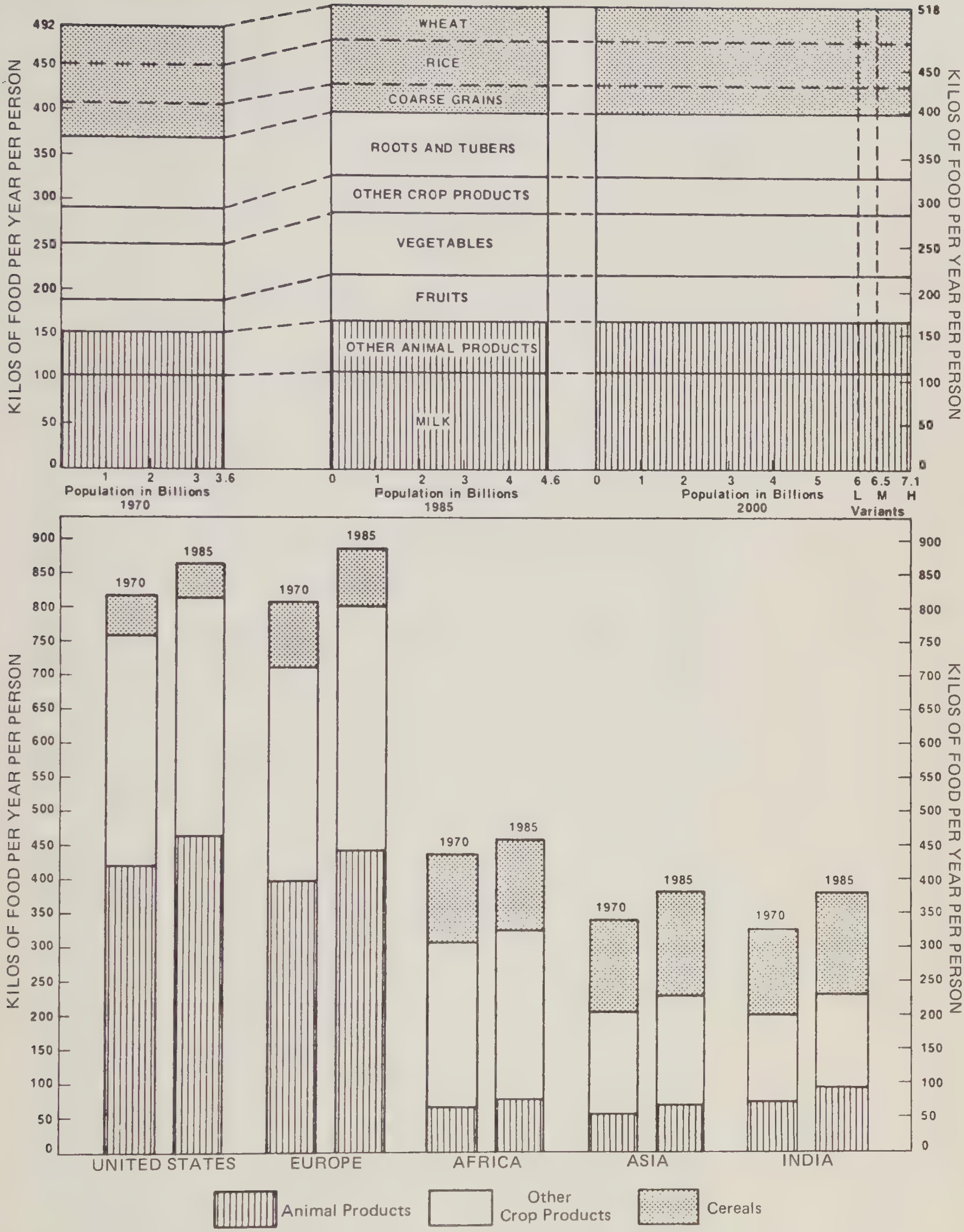


**FIGURE 1-5**. *A hungry world. Average per capita consumption of all food products by world and selected regions, 1970, 1985, 2000. Carter, H. O., ed.* A Hungry World: The Challenge to Agriculture. *Davis: University of California Division of Agricultural Sciences. Copyright © 1974.*

**Table 1-3. The amino acid composition of foods (mg amino acid per g protein in food).**

| *Commodity* | *S-AA*[a] | *Iso-leucine* | *Leucine* | *Lysine* | *Phenyl-alanine* | *Thre-onine* | *Tryp-tophan* | *Valine* |
|---|---|---|---|---|---|---|---|---|
| Cereals (70% to 75% extraction) | 36.8 | 38.4 | 68.8 | 20.8 | 51.2 | 28.8 | 9.6 | 46.6 |
| Starchy roots | 28.8 | 44.8 | 46.6 | 49.6 | 41.6 | 36.0 | 12.8 | 51.2 |
| Legumes | 12.8 | 52.8 | 70.4 | 62.4 | 41.6 | 36.8 | 8.0 | 56.0 |
| Vegetables and fruit | 11.2 | 43.2 | 57.6 | 44.8 | 36.8 | 38.4 | 8.0 | 54.4 |
| Meat | 36.8 | 51.2 | 78.4 | 81.6 | 41.6 | 44.8 | 12.8 | 52.8 |
| Eggs | 51.2 | 57.6 | 89.6 | 67.2 | 52.8 | 52.8 | 17.6 | 72.0 |
| Fish | 40.0 | 51.2 | 75.2 | 89.6 | 36.8 | 44.8 | 9.6 | 52.8 |
| Milk | 32.0 | 62.4 | 99.2 | 78.4 | 51.2 | 46.6 | 14.4 | 70.4 |

[a]Sulfur amino acids.

Source: Carter, H. O., ed. *A Hungry World: The Challenge to Agriculture.* Davis: University of California Division of Agricultural Sciences. Copyright ©1974.

fish, 89.6; and milk, 78.4. Thus, to get the required amount of lysine, one must eat three or four times as much cereal as meat. A mixture of plant and animal food is therefore advisable.

We can almost certainly expect that malnutrition and starvation will exist in some areas when food surpluses exist in other areas despite efforts to improve food distribution. A high level of food production exists in the tropics, but, because of population expansion, the demand for food is increasing faster (3.5% yearly) than agricultural production. Compare this rate with the 2.5% annual increase in food demand in the industrialized nations.

What lies in store? Habits and prejudices with respect to food hamper progress. Increasing prices are inhibiting the amount of grain being used for livestock feed, but no great decrease in the amount of grain to be used for livestock feed is expected. Animals generally consume relatively fibrous feeds, wastes, and other products not eaten by humans. Cattle, buffaloes, horses, and other animals used for draft must usually survive on what they can salvage from the fields and banks along the waterways. They get the "leavings," not the marketable feed.

Range cattle and sheep convert the feed they consume into edible meat; no human would eat much of what they consume. It is predicted that sheep will become more and more important because lambs can be brought to a marketable stage of finish without eating grown crops. If and when the human population crowds the steers and lambs from the finishing pens, there will still be range grasses and other forage for the cattle and sheep. Cattle and sheep roam the range and woodlands, producing beef and mutton which is less savory than choice steaks and roasts, but which is nevertheless good-quality human food produced from vegetation that no human would eat.

New sources of animal feed are certain to be developed from areas of the far north that are scarcely used today. Geneticists will direct their efforts to increasing the efficiency and profitableness of raising range animals by speeding their development from early life to slaughter, and finishing them on feeds that are not at all adapted for human consumption. Plant breeders will introduce range forages superior by far to anything we have today. So, although we may, in the years ahead, eat less meat (certainly fewer juicy steaks, if any at all), we will assuredly have good meat that will provide good-quality protein and flavor to the diet. In the meantime, we sincerely hope that world population growth will

stabilize and life will be made healthier and considerably less hazardous.

An example of how the livestock people can set about to solve a problem is the artificial insemination (AI) program. By the careful selection of dairy sires, the United States now produces as much milk nationally as it did 20 years ago with half as many cows as were in use then. Approximately half of the dairy cows in the United States are now artificially inseminated each year—approximately 2,745 cows to each bull in use in the AI program. Other countries, notably several in Europe, have exceeded the 50% mark; some inseminate 90% of the cows in the country. These figures show that AI has been, and can continue to be, a great tool for improvement. As research finds ways to freeze or otherwise preserve the semen of swine, sheep, goats, and poultry, great strides will be made in improving these species. Already 85% to 90% of the turkeys produced in the United States are from the AI program, which so far has relied on fresh, rather than stored, semen.

Fish is a great source of food of good quality. It is estimated that with the knowledge we have today, we can safely harvest 10 times the present "take" and continue to do so indefinitely.

Other possibilities that await further research are the proteins existent in single-celled fungi, bacteria, algae, and yeasts. Culture techniques and selection will open vast food possibilities here for people and animals.

In the chapters that follow, many aspects of animal science are discussed. It is hoped that the reader will come to readily visualize many ways to implement improvements in the production of livestock, with the result that our animals may serve most usefully in providing food, fiber, work, and pleasure for mankind.

## Study Questions and Suggestions

1. Is any significant amount of power provided today by people? By animals?
2. Can research results in one area of the world be applied to all areas?
3. How fast is our world population expanding?
4. Can we reasonably expect food production to keep pace with growth in numbers of people?
5. About how much food does a person consume in a year's time?
6. What are some essential differences between food of animal origin and food of plant origin?
7. What proportion of cattle and sheep feed could be eaten directly by humans?
8. How extensively is artificial insemination practiced in the world today?

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# 3. Milk and Milk Products

Most of the milk and milk products for people of the world are obtained from cows, goats, sheep, and buffaloes. However, milk from horses, donkeys, and sows is used by some people. Milk is composed of protein, fat, lactose (milk sugar), minerals, vitamins, pigments, enzymes, and water.

## Components of Milk

The solids in milk are generally considered in two categories—total solids and solids-not-fat. Total solids include fat, protein, lactose, and minerals. Solids-not-fat include these same substances with the exception of fat. The solids-not-fat are present in skim milk. The fat in milk, called milk fat, is used for making butter. Milk fat is the major component of cream. Milk fat from Jersey and Guernsey cows has a rich, yellow color; that from Holstein cows has a pale, yellow color; and that from goats is white. The yellow pigment, carotene, is broken down in milk fat into two molecules of vitamin A. In milk that contains yellow milk fat, no conversion of carotene to vitamin A has occurred. In milk fat that has no yellow color, all the carotene has been converted into vitamin A.

Goat milk differs from cow milk not only in pigmentation but also in the type of curd (solidified protein) that is formed by the action of acids and enzymes of the stomach on the milk. The type of curd formed from goat milk is more easily digested by some people than the type of curd formed from cow milk. Thus, people who cannot readily convert

carotene into vitamin A or those who find cow milk difficult to digest may find goat milk a more valuable food than cow milk.

Breeds of dairy cows vary in average percentage of milk fat and in total amount of milk produced. Jersey and Guernsey cows produce milk having a high percentage of milk fat (4.5% to 6.0%), but their total milk production is low. Holstein cows give large quantities of milk, but the percentage of milk fat is low—3.3% to 4.0%. When a cow starts producing milk after bearing a calf, the quantity of milk is intermediate. Production then increases until the peak of milk production is reached 2 to 3 months later. Towards the end of lactation (9th to 11th month of lactation), milk production declines. Percentage of milk fat is inversely related to the amount of milk given regardless of whether differences in the amount of milk given are due to differences in stages of lactation or to differences in breed. Thus, when milk production is high, percentage of milk fat is low; and, when milk production is low, percentage of milk fat is high. This does not mean that cows giving milk that has a low percentage of milk fat will produce less total milk fat.

The total amount of milk fat produced equals the fat percentage multiplied by the amount of milk produced. Holstein cows, for example, produce considerably more milk fat per lactation than Jersey or Guernsey cows because Holstein cows produce large quantities of milk. Thus, the total amount of milk fat produced is generally positively related to total milk production. When the amount of milk and fat produced is corrected for size or feed intake, the different breeds are seen to use feed with equal efficiency in producing milk and fat. Likewise, the dairy goat equals the dairy cow in efficiency of production of milk and milk fat even though it produces more milk per unit of body weight.

Butter was once an extremely important food item; however, the demand for it has been reduced due to the development of methods for processing plant fats into edible substitutes at a cost much lower than the cost of producing butter. The consumption of butter substitutes has resulted in people developing a taste for the substitutes so that some people now either prefer, or do not object to, substitutes. Because per capita consumption of butter has declined, the most important milk constituent today is its protein. Milk protein contains all the essential amino acids needed by humans. Therefore, low-fat milk is highly nutritious. It is especially good for children, who need large amounts of protein for growth.

## Bacterial Action—Good and Bad

Besides human beings, there are other organisms that thrive on milk—bacteria. In fact, milk is one of the best culture media for bacteria. This situation has both good and bad features. If milk is properly handled and if milk cows are provided proper facilities so that they can be kept healthy and clean, milk can be kept for a few days in refrigerated conditions. Most of the milk sold commercially in the United States is pasteurized. Pasteurization is a process of exposing milk to a temperature that will destroy all pathogenic bacteria but will neither reduce the nutritional value of the milk nor cause it to curdle. The old method of pasteurization was to hold milk at a temperature of 145°F for 30

minutes. This method has been discarded in favor of raising milk to a temperature of 161°F for 15 seconds, after which it is quickly cooled. The higher temperature now used destroys some organisms that might survive the 145°F temperature and less time is required.

By the introduction of proper bacteria into milk, several highly desirable foods such as the wide variety of cheeses can be made. Pathogenic bacteria also thrive in milk. People who consume raw milk should, therefore, be certain that this milk comes from healthy animals, is produced under sanitary conditions, and is handled by healthy people. Brucellosis (undulant fever) and tuberculosis are two diseases that can be transmitted either from diseased cows or diseased persons handling milk to those who consume the milk.

## Nutritional Importance of Milk

The protein of milk is composed of globulins, casein, and lactalbumin. The globulins of milk are structural parts of antibodies. Casein is the largest protein constituent of milk. It has many uses in addition to providing protein in the diet. Lactalbumin is part of the enzyme system that synthesizes lactose in the mammary gland. It is secreted into milk as a by-product and becomes part of milk protein. The first milk a female produces after the young is born is called *colostrum.* It contains many antibodies which give the newborn protection from harmful microorganisms that invade the body of the newborn and cause illness. The newborn animal has not developed any antibodies of its own because it has not been exposed to any disease-causing microorganisms. The gut wall of the newborn is quite porous and permits antibodies in colostrum to enter the body. Within a few days the gut wall becomes less porous and the antibody content of the milk diminishes, but the antibodies that have been absorbed into the body of the newborn give it protection (immunity) until it can develop antibodies in its own body. Colostrum is not used for human consumption.

Other constituents of milk are lactose (milk sugar), minerals such as calcium and phosphorus (both of which are important in bone growth and other body functions), and vitamins. Milk is quite low in iron; therefore young animals consuming nothing but milk may develop anemia. Baby pigs produced in confinement are especially likely to develop anemia if no iron is supplied. When young children consume large quantities of milk at the expense of meat, one should give them some source of iron. Milk contains several important vitamins such as vitamin A, which helps keep the intestinal tract and skin in proper repair, the vitamin B complex, and vitamins C, D, and E. Vitamin D, along with calcium and phosphorus, is important in bone growth and repair. Vitamin C prevents scurvy, a disease characterized by bleeding, spongy gums and loose teeth.

In addition to cheese, ice cream, and various iced milk drinks, many delectable and nutritious foods are prepared from milk. Milk may have a portion of the water it contains removed and sugar added to produce condensed milk, or it may be dried to produce either dried whole milk or skim milk. Dried, condensed milk may be reconstituted to provide milk to drink or it may be used in cooking with or without reconstitu-

**Table 3-1. Annual per capita consumption of dairy products in the United States (1974).**

| *Product* | *Consumption in lbs.* |
|---|---|
| Fluid whole milk | 200.0 |
| Lowfat fluid milk | 78.6 |
| Fluid cream | 5.7 |
| Butter | 4.3 |
| Cottage cheese | 4.7 |
| American and other cheese | 14.2 |
| Evaporated and condensed milk | 5.1 |
| Ice cream | 17.7 |
| Ice milk | 7.7 |
| Nonfat dry milk | 3.8 |

Source: From USDA. *1975 Handbook of Agricultural Charts.* Agriculture Handbook No. 491. U.S. Department of Agriculture, October 1975.

tion. Buttermilk is produced when butter is made, or it can be cultured from milk by the use of proper bacteria. Cottage cheese is made by curdling the milk and removing most of the liquid (whey).

Much of the diet of people in the United States is composed of milk or products made from milk. The per capita consumption of milk and milk products in the United States is presented in Table 3-1. One notes from this table that the consumption of low-fat and nonfat milk has become important in the diet because people are avoiding milk fat.

The consumption of milk and milk products in the United States is much lower than that in some other countries. For example, as estimated by the Milk Industry Foundation (1976), annual consumption of fluid milk per capita in the United States is 244 lbs.; in Finland, 564 lbs.: annual per capita consumption of butter in the United States is 4.7 lbs.; in New Zealand, 32.8 lbs.: annual per capita consumption of cheese in the United States is 14.5 lbs.; in France, 33.3 lbs.

Much of the fluid milk consumed in the United States is homogenized. Homogenization is a process of making a stable emulsion of milk fat and milk serum. There are three types of homogenizers: the high-pressure type, the low-pressure, rotary type, and the sonic vibrator. The high-pressure type forces milk through a small orifice, which causes the fat globules to break apart and remain dispersed in a stable emulsion. Exceedingly high pressures of 5,000 lbs. per sq. in. may be used in this process.

The low-pressure, rotary type homogenizer employs pressures of less than 500 lbs. per sq. in. The rotary action shears the fat globules apart.

The sonic vibrator type of homogenizer subjects milk to high frequency vibrations which tear the fat globules apart.

Fat globules in milk average about 6 micrometres ($\mu$m) in diameter.[1] Homogenization results in fat globules that average less than 2 $\mu$m in diameter. A cream line does not appear in homogenized milk and churning of homogenized milk does not result in butter formation. To visualize how small the fat globules in homogenized milk are, one should remember that 25,000 $\mu$m equal approximately 1 inch.

1. In accordance with the practice of the International Bureau of Weights and Measures, the American word *meter* will be spelled *metre.*

**Table 3-2. Average percentage composition of milk from selected mammals.**

| *Mammal* | *Water* | *Total solids* | *Fat* | *Protein* | *Lactose* |
|---|---|---|---|---|---|
| Human | 87.8 | 12.2 | 3.8 | 1.2 | 7.0 |
| Cow | 87.3 | 12.7 | 3.9 | 3.3 | 4.8 |
| Goat | 87.6 | 12.4 | 3.7 | 3.3 | 4.7 |
| Water buffalo | 76.8 | 23.2 | 12.5 | 6.0 | 3.8 |
| Ewe | 81.6 | 18.4 | 6.5 | 6.3 | 4.8 |
| Sow | 82.4 | 17.6 | 5.3 | 6.3 | 5.0 |
| Mare | 90.2 | 9.8 | 1.2 | 2.3 | 5.9 |

Source: From *Introduction to Livestock Production,* Second Edition, by H. H. Cole. W. H. Freeman and Company. Copyright© 1966.

Homogenized milk will likely deteriorate by becoming rancid more rapidly than nonhomogenized milk, due to the greater surface area of the fat globules upon which lipolytic enzymes can act. To avoid rancidity of homogenized milk, one can pasteurize the milk prior to or immediately following homogenization. This will destroy the action of the lipolytic enzymes.

## Species Differences in Milk Composition

Milk from different animals exhibits rather large differences in percentages of certain constituents. For example, water buffaloes, ewes, and sows all produce milk that is relatively high in total solids, fat, and protein, and low in water content. Milk from mares is low in fat. Human milk is low in protein (Table 3-2).

Schmidt (1971) gives the composition of milk from reindeer as 36.7% total solids, 22.5% milk fat, 14.2% solids-not-fat, 10.3% protein, 2.5% lactose (milk sugar), and 1.4% minerals. The milk from reindeer is the highest in nutrient constituents of any animal that might someday be used for milk production.

## Consumer Protection

State and federal agencies protect the consumer by several safeguards, such as sanitation requirements of production facilities, checks on bacterial counts of commercial milk, and checks on alterations of milk that occur when water is added to give greater volume. From a health standpoint the requirements that bacterial counts be low and that milk be pasteurized are the most important safeguards. The consumer can be assured of obtaining a safe, desirable product when milk and milk products are purchased.

## Study Questions and Suggestions

1. (True or False)
   a. The percentage of fat is inversely related to amount of milk produced, but the amount of fat is directly related to the amount of milk produced.
   b. The most important solid in milk for human nutrition is milk fat.

c. The yellow color of milk is a good indicator of its milk fat content.
d. Milk is high in most minerals, but it is very low in iron content.
e. Dairy cows and dairy goats are approximately equal in efficiency of milk production.

2. a. What are the solids-not-fat of milk?
   b. What is the first milk given after a female's young are born called? Is it used for human consumption?
   c. What safeguards do we have to protect the consumer who purchases milk?
   d. What are five food products made from milk?
   e. What vitamins are normally present in milk?
3. a. Why is goat milk given to some people in preference to cow milk?
   b. Milk is a perfect medium for bacterial growth. What hazards does this situation present? What advantages?
   c. What variations are particularly noticeable in milk constituents from different species?
   d. Why has the consumption of butter not increased in proportion to population increase in the United States?
   e. Is milk a complete and perfect food for human infants? Why or why not?

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# 5. Reproduction and How It Works

If a livestock enterprise is to be profitable, the operator must exercise control over reproduction.

Animals of today have been improved over the years, presumably to better meet the current market demands. Improvement has come in conformation, in efficiency, in rate and economy of gain in meat producers, and in the production of milk in all months of the year (not only in the spring) in dairy cattle. However, too often when selection was made for these desirable traits, little or no effort was made to maintain, let alone improve, the fertility of the stock. So when we speak of "improved" livestock we should ask "improved in respect to what?"

If, for example, our goal is to maintain an even volume of milk for a herd of dairy cattle each month of the year, we must insure that the cows can be "freshened" (bred and calved out so that they will start milking) monthly throughout the year and not just at any time, or only in spring, as was the wild pattern. Viable semen must be available each and every month, despite the tendency of the semen of certain bulls to fluctuate in quality during the year. Individual cows vary in their expression of estrus (the period of mating activity of a female mammal, also called "heat"); hence, some cows may not be identified soon enough to prevent a delay in having them bred, thereby decreasing the efficiency of the operation.

Thus, a person who insists on exercising control over a livestock operation must be knowledgeable regarding the many details of reproduction and how animals can be made to reproduce according to plan. The

This chapter was written by Dr. Fred F. McKenzie specially for this book.

**Table 5-1. Quantitative characteristics of semen of several animals.**

| | Volume per ejaculate | | Sperm concentration per $mm^3$ | | Volume of good diluted or undiluted semen recommended per insemination (ml) |
|---|---|---|---|---|---|
| | Approximate range (ml) | Most common volume (ml) | Range (x 1000) | Most common (x 1000) | |
| Cattle | 0.5 to 14.0 | 3.0 to 4.0 | 300 to 2,000 | 800 | 0.50 to 1.5 |
| Horses | 40.0 to 320.0 | 75.0 to 150.0 | 30 to 800 | 60 to 200 | 10.00 to 30.0[b] |
| Swine | 125.0 to 500.0[a] | 200.0 | 25 to 1,000 | 100 | 50.00 to 100.0 |
| Sheep | 0.5 to 2.0 | 0.8 | 500 to 6,000 | 1,000 | 0.10 to 0.2 |
| Goats | 0.2 to 2.5 | 1.0 | 1,000 to 5,000 | 3,000 | 0.10 to 0.5 |
| Dogs | 2.0 to 19.0 | 4.0 to 6.0 | 1,000 to 9,000 | 300 | — |
| Rabbits | 0.4 to 6.5 | 1.0 | 100 to 2,000 | 700 | 0.25 to 1.0 |
| Turkeys | 0.1 to 0.7 | 0.3 | 3,000 to 13,000 | 7,000 | 0.05 |
| Chickens | 0.1 to 1.5 | 0.6 | 50 to 6,000 | 4,000 | 0.10 |
| Humans | 2.0 to 6.0 | 3.0 | 50 to 200 | 100 | — |

[a]Gel free.

[b]B. W. Pickett and associates had good results with 1.5 ml (gel free).

Source: This table is an updated and modified version of Table 3 prepared by F. F. McKenzie in Lambert, W. V., and McKenzie, F. F. 1940. *Artificial Insemination in Livestock Breeding.* USDA Circular 567.

**Table 5-2. Duration and frequency of heat, time of ovulation, and optimum time for insemination in farm animals in normal condition.**

| Animal | Duration of heat: Approximate range days | Duration of heat: Approximate range hours | Duration of heat: Most common duration days | Duration of heat: Most common duration hours | Length of cycle[a]: Range days | Length of cycle[a]: Most common duration days | Approximate time of ovulation in relation to heat | Optimum time to breed or inseminate in the heat period | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Cow | | 10 to 27 | | 16[b] | 19 to 23 | 20 | 10 hours after end of heat. | Preferably twice, once shortly after onset of heat and again 12 to 20 hours after onset; if but once, 12 to 20 hours after onset; earlier in warm climates and with humped cattle. | Heat period shorter in beef cattle than in dairy cattle. Heat shorter and harder to detect in warm climates and in humped cattle (in many instances, lasts only 2 to 8 hours). |
| Water buffalo | | 20 to 28 | | 24 | 18 to 24 | 21 | Late heat to 10 hours after. | When heat is well established. | Ovulation without heat ( = silent heat) is common (15%-35%). |
| Mare | 1 to 37 | | 3 to 7 | | 10 to 37 | 18 to 24 | 2 days before end of heat until 1 day after. | If feasible, once daily after first day of heat in light mares, after second day in draft; if bred only once, on the third day. When the mare is in heat 3 days after breeding, breed a second time. If the ovary is palpated, breed when there is a large, slightly relaxed ovarian follicle, 2 to 5 cm in diameter. | Foal heat in mares usually lasts 5 days but may range from 1 to 10 days. Mares usually come into heat 5 to 10 days after foaling but this is the least fertile period. |
| Sow (mature)<br>Sow (immature) | 2 to 4 | <br>40 to 48 | 3<br>2 | | 19 to 23 | 20 to 22 | Early on the second day of heat. | Late on the first day of heat, preferably on second day. | Sows usually come into heat 3 to 4 days after weaning pigs; earlier if the litter is small. |
| Ewe | | 20 to 42 | | 30 | 14 to 19 | 16 to 17 | About 1 hour before the end of heat. | During the latter half of heat, or, if feasible, at 12-hour intervals as long as in heat. | There is evidence that the duration of heat is longer in some breeds, as the Lincoln and Corriedale, the mean duration being about 40 hours. |
| Doe (goat) | | 20 to 80 | | 39 | 12 to 27 | 16 to 18 | Usually on second day. | During latter half of heat. | |
| Bitch (dog) | 4 to 13 | | 9 | | 126 to 240[c] | 180 | 24 to 48 hours after onset of heat (after first acceptance of copulation). | On ninth to 13th day after beginning to bleed, blood may be dark brown on the first day of true heat. | Much individual variability exists in estrual cycle. Each bitch usually remains quite constant to one particular period. Length of cycle is influenced to some extent by such factors as breed and age. |
| Doe (rabbit) | | | | | | | 8 to 10 hours after copulation. | Breeding 2 to 5 hours after first copulation increases litter size. Breeding later than 5 hours after ovulation reduces litter size. | No regular heat cycle exists, but there is evidence that there are certain periods of greater receptivity. If nutritive conditions are favorable and the does are not molting and are in proper breeding condition, they may be mated at any time if restrained. |
| Cat | | | 4 | | | 8 to 9 | 24 hours after copulation. | | If there is no mating, heat will last 9 to 10 days and recur in 15 to 21 days. |
| Mink | | | 2 | | | | 40 to 50 hours after copulation. | | |

[a]The length of the heat (estrual) cycle is the interval from the beginning of one heat period to the beginning of the next.

[b]About 3 hours less after copulation.

[c]Two breeding seasons yearly.

Source: This table is an updated and modified version of Table 2 prepared by F. F. McKenzie in Lambert, W. V., and McKenzie, F. F. 1940. *Artificial Insemination in Livestock Breeding.* USDA Circular 567.

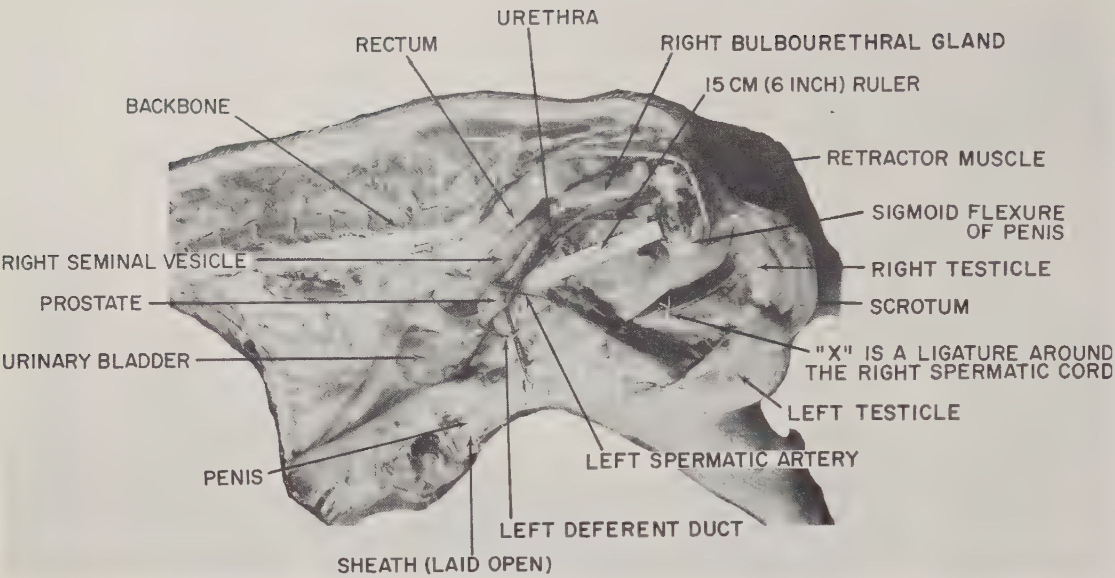



**FIGURE 5-1.** *Reproductive organs of the boar (in natural position except that the left testicle and connecting tissues are pulled downward to expose the right testicle for the photograph).*

operator should know what the reproductive mechanism consists of, what makes that mechanism function, and how its functions can be altered to better suit the desired goals. It thus behooves the person who wishes to operate a livestock breeding enterprise to know the anatomy of the reproductive organs, the function (physiology) of these organs, what factors affect them, and, especially, what may be done to stimulate or retard them so that the reproductive process can be controlled precisely and effectively.

Many useful details pertaining to the breeding of animals, such as the characteristics of their semen, the duration and frequency of heat, the time of ovulation, and the optimum time to breed are presented in Tables 5-1 and 5-2.

## Male Organs of Reproduction

The organs of reproduction of the typical male farm mammal consist, first of all, of the two *testicles,* which are bean-shaped organs held in the *scrotum. Spermatozoa* (male sex cells) are formed in the tiny seminiferous tubules of the testicles. The spermatozoa from each testicle then pass through very small tubes into an *epididymis*, which is a tube that is held in a covering applied closely to the exterior of the testicle. Each epididymal tube is 30 to 35 metres (m) long in the bull. Each epididymal tube leads to a larger tube, the *deferent duct* (also called the *vas deferens* or *ductus deferens*). The two deferent ducts converge from the left and right sides of the body to connect with the *urethral canal* at its upper end, very near to where the *urinary bladder* opens into the *urethra.* The urethra is the large canal that leads through the *penis* to the outside of the body. The penis has a triple role: (1) that of a passage for urine, (2) that of a passage for the products originating in the other organs of reproduction, and (3) that of an organ of copulation. The *seminal vesicles* and the *prostate gland* are also found at the base of the urinary bladder. The left and right parts of the seminal vesicles, which

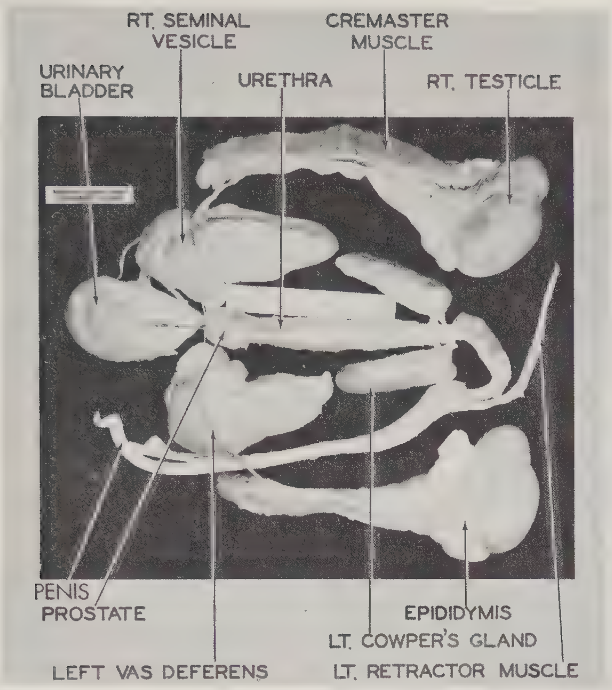



**FIGURE 5-2.** *Reproductive organs of the boar dissected and laid flat on a table. The scale is a 15-cm ruler. Note the relatively large accessory organs (seminal vesicles and bulbourethral glands).*

**FIGURE 5-3.** *Reproductive organs of the bull. The operator is picking up the ampulla of the right deferent duct. Photograph by USDA.*

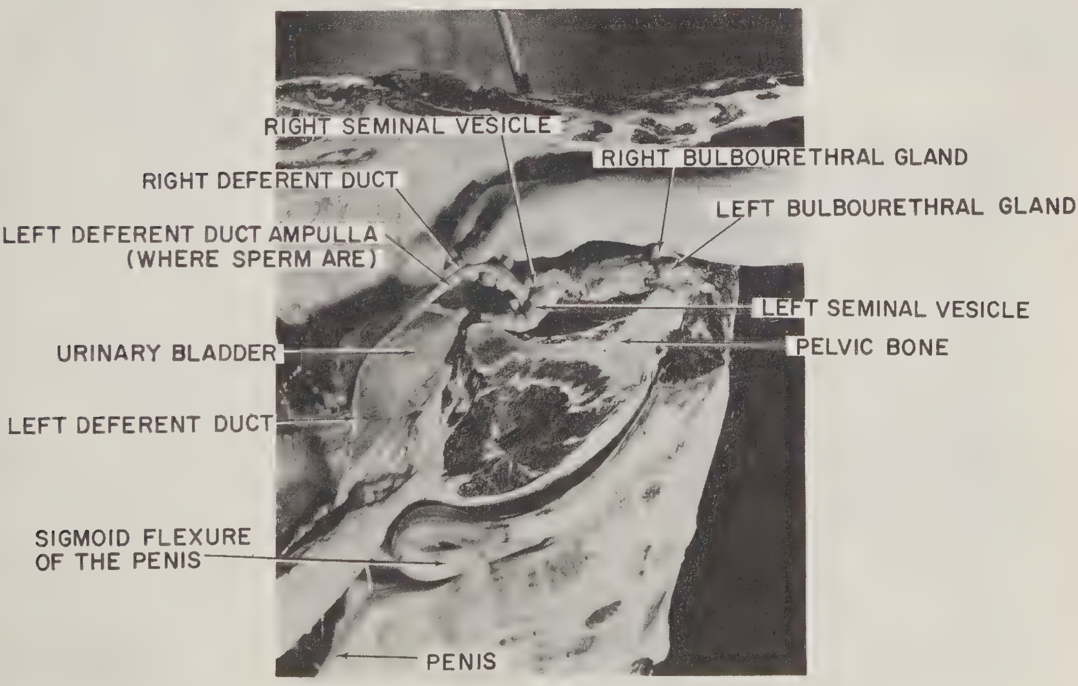


FIGURE 5-4. *A diagrammatic sketch of the structure of cattle sperm. Courtesy of Dr. Arthur S. H. Wu, Oregon State University.*

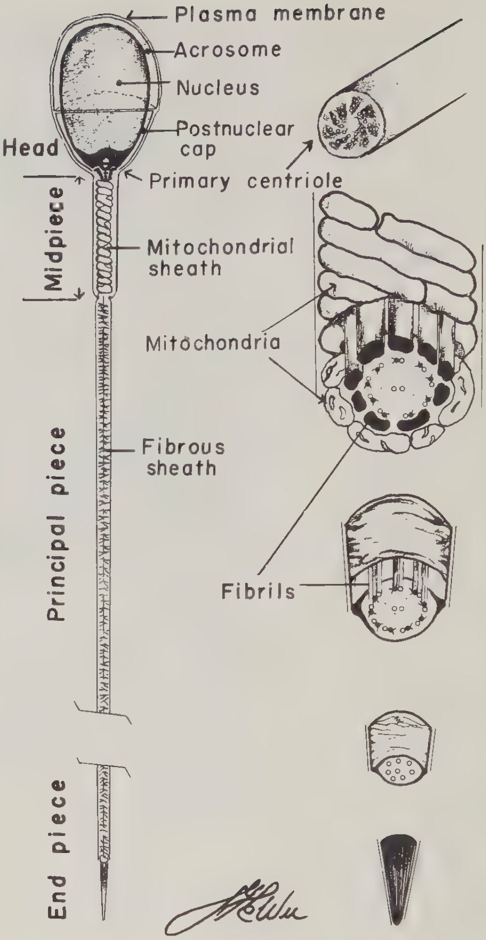




FIGURE 5-5. *A spermatozoan (sperm cell) from a bull (7000X) viewed through the electron microscope after treatment with 0.15 N NaOH at 25°C for 16 hours. Note how the covering membrane of the neck region of the sperm has been removed, exposing the nine fibrils of the axial filament. Three filaments are larger than the rest. From Wu, A. S. H., and McKenzie, F. F.* Microstructure of Spermatozoa After Denudation as Revealed by the Electron Microscope. *Journal of Animal Science 14(4):1151-66, 1955.*

FIGURE 5-6. *Bull sperm (12,000X) viewed with the scanning electron microscope showing the depth of the sperm head covered by the raised acrosome. Courtesy of Dr. Arthur S. H. Wu, Oregon State University.*

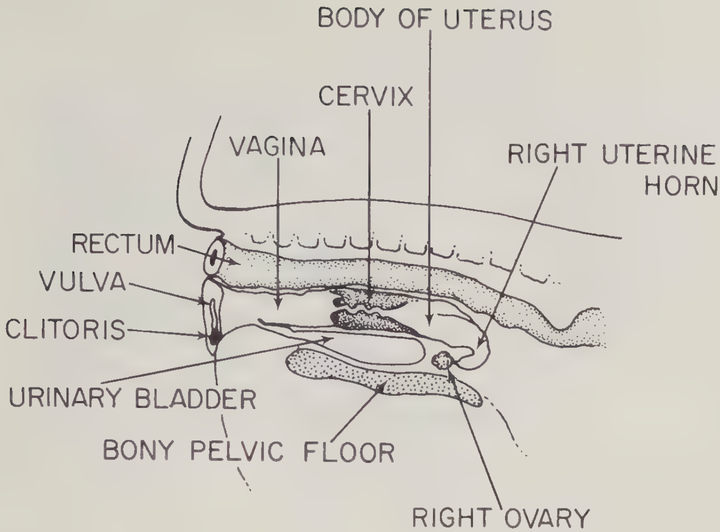


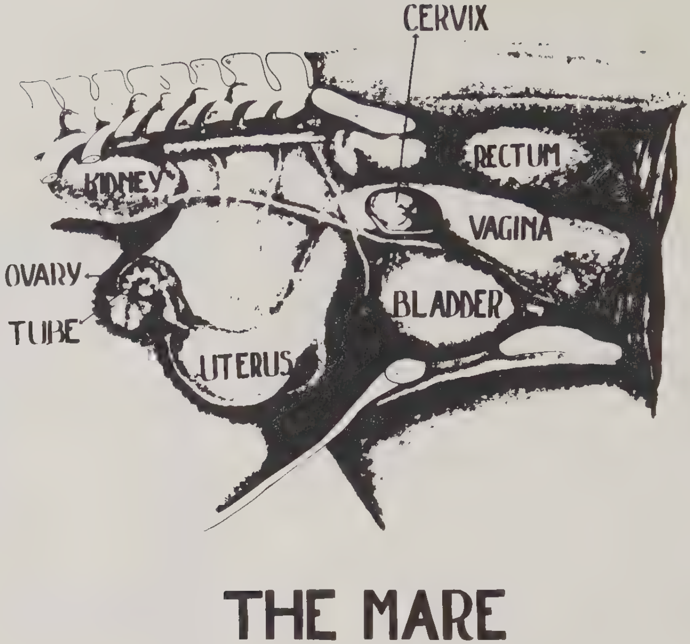

**FIGURE 5-7.** *Reproductive organs of the young cow. Note that the cervix, uterus, and ovaries are located on the floor of the bony pelvis in the young cow so that they are readily palpated. In an older cow, the organs are pulled forward into the body cavity so that the uterus and ovaries are beyond the pelvis. In the young cow, one's arm need not enter the rectum more than 20 cm to reach the cervix and/or the ovaries. Note how easy it is to pass a tube into the bladder instead of into the cervix!*

lie against the urinary bladder, consist of glandular tissue that supplies a secretion that moves through the exit tube of each seminal vesicle into the urethra. The prostate gland is composed of a group of some 12 or more glandular tubes, each of which empties into the urethra, also near the opening from the urinary bladder and dorsal to (above) it. Another gland, the *bulbourethral (Cowper's) gland*, which also empties its secretion into the urethral canal, is approximately 40 centimetres (cm) posterior to (behind) the prostate. The reproductive organs of the bull and the boar are shown in Figures 5-1, 5-2, and 5-3. Details of the structure of the spermatozoa of the bull are shown in Figures 5-4, 5-5, and 5-6.

## Female Organs of Reproduction

The organs of reproduction of the typical female farm animal consist, first of all, of a pair of *ovaries*, which are suspended by ligaments just back of the kidneys, and a pair of open-ended tubes, the *oviducts* (also called the *Fallopian* or *ovarian tubes*), which lead directly into the *uterus* (*womb*). The uterus itself has two horns, or branches, that merge together at the lower part into one structure in our farm mammals, so that the lower opening, or exit, from the uterus is a canal. This canal is called the *cervix*. The cervix is surrounded by muscles. Its surface is fairly smooth in the mare and the sow, but is folded in the cow and the ewe (see Figure 6-2, Chapter 6). The cervix opens into the *vagina*, a relatively large canal or passageway that leads posteriorly to the external parts, which are the *vulva* and its *clitoris*. In the cow, the *urinary bladder* empties into the vagina from the ventral (bottom) side about 75 millimetres (mm) from the vulva and just posterior to a *sphincter* muscle which surrounds the canal and helps prevent urine from flowing forward. That portion of the passageway from the sphincter to the vulva is called the *vestibule* of the vagina. The reproductive organs of the cow and the mare are shown in Figures 5-7 and 5-8. What do the male and female reproductive organs do? How do they each play a part in fertility and reproduction?

FIGURE 5-8. *Reproductive organs of the mare.*




## Functions of the Male Organs of Reproduction

**Testicles.** The testicles produce (1) the sperm cells, or spermatozoa, that fertilize the eggs, or ova, of the female, and (2) a hormone called testosterone that conditions the male so that his appearance and behavior are masculine. Thus, if both testicles are removed (as is done in castration of males), the individual loses his sperm factory and is left sterile. Also, without testosterone his masculine appearance fades and he approaches the status of a neuter, that is, an individual whose appearance is somewhere between that of a male and that of a female. To illustrate, the effect of castration of the bull calf is to make him a steer, that is, a sterile individual lacking prominent horn development, lacking the crest, or powerful neck, of the bull, lacking to a degree the bull's propensity to grow to his full potential, and having a weaker voice than if he had been left entire. If the animal is castrated while he is immature, such organs of reproduction as the deferent ducts, seminal vesicles, prostate, and bulbourethral glands all but cease further development. If castration is done in the mature animal, the remaining genital organs tend to shrink in size and in function. The penis is affected also, being smaller in the castrate than in the entire male.

A series of injections of male hormones restores the male appearance to a castrate, including restoration of the expected size of the male sex organs. A successful graft of testicular tissue to a castrate will do the same. However, it must be noted that the sperm-producing capacity of this male is not restored by such treatment. Hence he will remain sterile, even though he may be rejuvenated in respect to his accessory organs of reproduction, his growth propensity, and his behavior as an aggressive male.

Within each testicle, the sperm cells are generated in the seminiferous tubules and the testosterone is apparently produced in the cells between the tubules, which are called interstitial cells (cells of Leydig).

**Epididymis.** The epididymis affords the opportunity for the sperm cells, which enter it from the testicle, to actually mature. In passing through this very long tube (30 to 35 m in the bull, longer in the boar and stallion), the sperm acquire more and more the capacity to fertilize ova. Sperm taken from the part of the epididymis nearest the testicle are not likely to be able to fertilize ova, whereas those taken from areas farther along this long, winding tube increasingly show the capacity to fertilize.

In the sexually mature male animal, sperm reside in the epididymis in vast numbers. Of course, in time they age and degenerate and are absorbed in the part of the epididymis furthest from the testicle unless they have been moved on into the deferent ducts and have been ejaculated (Figures 5-1, 5-2, and 5-3). The epididymis is a very rich source of enzymes and these go into the semen plasma.

**Scrotum.** The scrotum is a two-lobed sac that contains and protects the two testicles—but it does more. It is the scrotum that regulates the temperature of the testicles, maintaining them at a temperature lower than body temperature—1.6°C to 3.9°C lower in the bull and 5°C to 7°C lower in the ram and the goat. When the environmental temperature is low the tunica dartos muscle of the scrotum contracts, drawing the testicles toward the body and its warmth; when the environmental temperature is high this muscle relaxes, permitting the testicles to drop away from the body and its warmth. It should be noted that this heat-regulating mechanism of the scrotum begins at about the time of puberty when the testicular hormone comes into effect.

When the environment is so hot that the testicles cannot cool sufficiently, the formation of sperm is impeded and a temporary condition of lowered fertility is produced. Providing shade, keeping the males in the shade during the heat of the day, providing cold water to drink and at the same time providing cool air to breathe over the cold water, or even providing air conditioning are ways to manage and prevent this temporary sterility.

**Deferent ducts.** The deferent ducts (vasa deferentia) are essentially transportation tubes that carry the sperm-containing fluid from each epididymis to the urethra. The deferent ducts join the urethra near its origin as the urethra leaves the urinary bladder. In the mature bull, the deferent duct is about 3 mm in diameter except in its upper part where it widens into a reservoir, or ampulla, about 10 to 17 cm long and 1 cm wide. The ampulla of the deferent duct is profusely supplied with nerves from the pelvic plexus of the sympathetic nervous system.

Under the excitement of anticipated mating, the secretion loaded with spermatozoa from each epididymis is propelled into the deferent duct and accumulates in the ampulla of the deferent duct. This brief accumulation of semen in the ampulla is an essential part of sexual arousal. The sperm reside briefly in the ampulla until the moment of ejaculation, when the contents of each ampulla are pressed out into the urethra, and then through the urethra and the penis enroute to their deposition in the female tract (see Figure 5-3).

The male may ejaculate without copulation, a process called masturbation. The ampulla is found in the bull, stallion, goat, and ram—species that copulate rapidly. It is not present in the boar or dog, animals in which copulation normally takes several minutes. In such

animals, sperm in numbers travel all the way from the epididymis through the entire length of the deferent duct and the urethra. On close observation of the boar at the time of mating, one can see the muscles over the scrotum quivering rhythmically as some of the contents of each epididymis are propelled into the deferent duct and on into the urethra. This is in contrast to the sudden expulsion of the contents of the ampulla of the deferent duct at the height of the mating reaction, or orgasm, in the bull, stallion, ram, and goat.

**Urethra.** The urethra is a large, muscular canal extending from the urinary bladder; the bladder empties into the upper and inner end of the urethra. The urethra runs posteriorly through the pelvic girdle and curves downward and forward through the full length of the penis. Very near the junction of the bladder and urethra, the tubes from the seminal vesicles and the prostate join this large canal. The bulbourethral gland joins the urethra at the posterior floor of the pelvis. The urethra is lined with many tiny glands (Littre's glands), whose watery secretion is clear and high in mucoproteins. This secretion composes much of the pre-sperm portion of the ejaculate.

**Seminal vesicles.** The seminal vesicles are sizable organs which lie over the neck of the bladder and on either side of the pelvic urethra and which open into the urethra near the place where the deferent ducts open into it. In the bull the seminal vesicles are about 10 cm long and 2.5 cm in diameter. The boar's seminal vesicles are large, thin-walled, pyramid-shaped glands in which the apex points posteriorly. The combined weight of the two glands varies from 150 to 850 g and the contents from 38 to more than 500 g. The fluid of the boar is a gray, opaque color, is of medium viscosity, and has a pH of about 6.7 (McKenzie *et al*, 1938).

To the semen (the fluid that contains the sperm), the seminal vesicles contribute ascorbic acid, citric acid, inorganic phosphorus, acid-soluble phosphorus, and the bulk of the seminal fructose, and, in the case of the boar, much ergothioneine. No chlorides come from the seminal vesicles. Seminal vesicles are prominent in the bull, stallion, ram, and goat, but are absent in the dog and cat.

**Prostate gland.** The prostate gland also lies near the neck of the bladder and surrounds the urethra. In the bull the main part of the prostate is about 37 mm across (left to right) and 12 mm in diameter. Additional prostate tissue is scattered among the muscles of the pelvic urethra. This scattered portion of the prostate is appropriately called the disseminated part (pars disseminata). The prostate has a muscular wall. It empties into the urethra through a series of small openings. It supplies antagglutin and minerals to semen plasma.

**Bulbourethral (Cowper's) glands.** The bulbourethral glands are located on either side of the pelvic urethra, just posterior to the urethra-penis where the urethra-penis dips downward in its curve. The bulbourethral glands are covered by fibrous tissue. They are small in farm animals, except in the boar. In the bull, they are about 25 by 12 mm, but in the boar they are comparable in shape and size to a banana (15 cm by 3 to 5 cm). The secretion from the bulbourethral glands is thick and viscous, very slippery, or lubricating, and whitish in color. It has a high sialoprotein content. This sialoprotein has much to

do with the formation of the gelatinous fraction of the semen in the boar and, probably, in the stallion.

**Penis.** The penis is the organ of copulation. It also provides a passageway for the escape of urine. It is a muscular organ characterized especially by its spongy, erectile tissue that fills with blood under considerable pressure during periods of sexual arousal, making the organ rigid, or erect.

The penis of the bull is about 1 m in length and 3 cm in diameter, tapering to the free end. In the bull, boar, and ram the penis is S-shaped when relaxed (Figures 5-1 and 5-3). This S-curve, or Sigmoid flexure, is eliminated when the penis is erect and in copulation. The S-curve is restored after copulation when the relaxing organ is drawn back into its sheath by a pair of retractor muscles. The stallion penis has no S-curve; it is enlarged by engorgement of blood in the erectile tissue.

The free end of the penis is termed the glans penis. The opening in the ram penis is at the end of a hairlike appendage that extends about 20 to 30 mm beyond the larger penis proper. This appendage also becomes erect and whirls around in a circular fashion when free. It does not regularly penetrate the ewe's cervix, as some investigators claim. Only a small portion of the penis of the bull, boar, ram, and goat extends beyond its sheath during erection. The full extension awaits the thrust after entry into the vagina has been made. The bull, ram, and goat ejaculate very rapidly, in fact, almost instantaneously, whereas the boar, like the dog, copulates for several minutes (8 to 12 minutes is typical in swine). The stallion and ass usually extend the penis completely before entry into the vagina.

It is emphasized here that all these accessory male sex organs depend on the hormone of the testicles (testosterone) for their tone and normal condition. This is especially apparent when the testicles are taken away (at castration); the usefulness of the accessory sex organs is then diminished if not terminated. Boars at least retain their fertility without seminal vesicles and bulbourethral glands (McKenzie *et al*, 1938).

## Functions of the Female Organs of Reproduction

**Ovaries.** The ovaries produce eggs (female sex cells, also called ova) and hormones. Each egg, or ovum, is generated in a recently formed follicle within the ovary. Some tiny follicles develop and ultimately attain maximum size, about 10 mm in diameter, after having migrated from deep in the ovary to the surface of the ovary. These mature (or Graafian) follicles rupture, thus freeing the ovum (ovulation). Many of the tiny follicles grow to various stages, cease growth, deteriorate, and are absorbed (Figures 5-9, 5-10, and 5-11).

After the egg escapes from the mature follicle, the follicle is turned into a "yellow body," or corpus luteum, which becomes a vitally important structure if pregnancy occurs (see p. 49).

**Ovarian tubes.** The ovarian tubes (oviducts, Fallopian tubes) receive the ova immediately after the ova leave the ovaries. The ova are tiny, 200 m or less in diameter (200 $\mu$m = 1/5 mm), which is approximately the size of a dot made by a sharp pencil. The ovarian tubes also receive the sperm after the female is inseminated (naturally or artificially) and

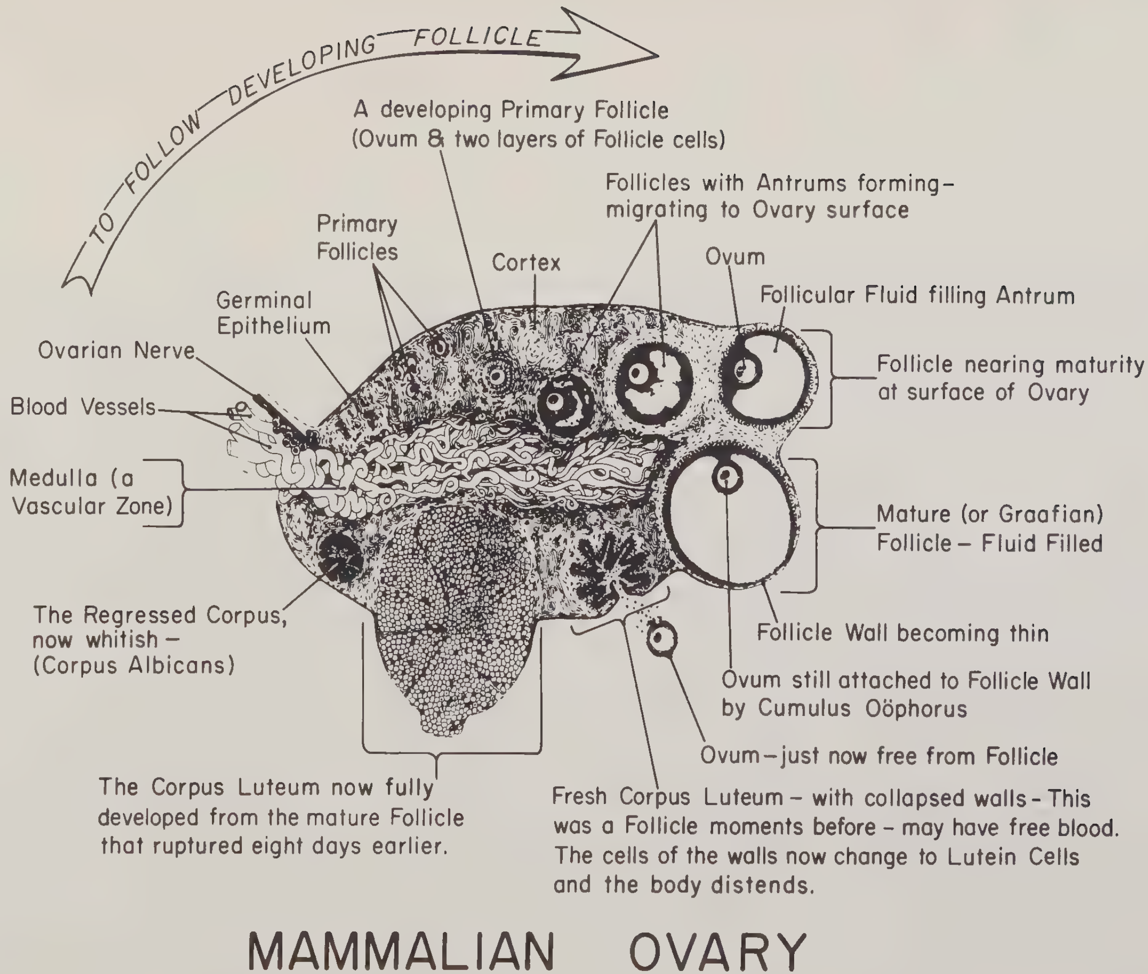



**FIGURE 5-9.** *A cross section of the bovine ovary showing how a follicle develops to full size and then ruptures, thus allowing the egg to escape. The follicle then becomes a "yellow body" (corpus luteum) which is actually orange colored in cattle. The corpus luteum degenerates in time and disappears. Of course, many follicles cease development, stop growing, and disappear without ever reaching the mature stage. From Bone, J. F.* Animal Anatomy and Physiology. *4th ed. Corvallis: Oregon State University Book Stores. Copyright © 1975.*

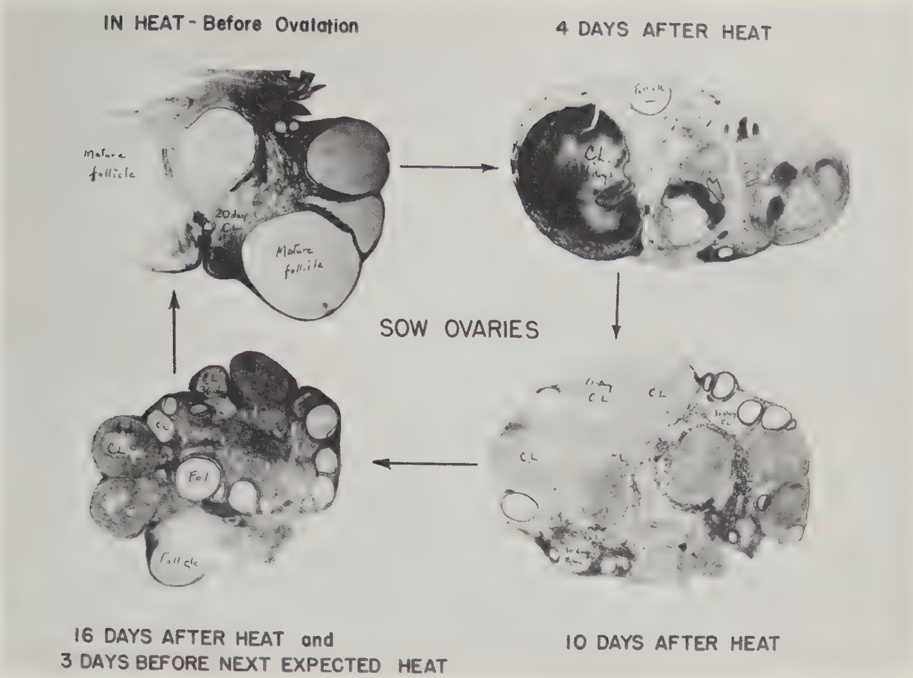



**FIGURE 5-10.** *Changes in the sow ovary shown through one heat until the time of the next heat. Note that the egg-containing follicle attains mature size only shortly before rupturing. See how the corpus luteum (successor to the mature follicle) builds and fills with luteal tissue to midcycle, then disintegrates (center liquefaction) in the nonpregnant sow. Photographs are of actual sections of sow ovaries (approximately 1X actual size).*

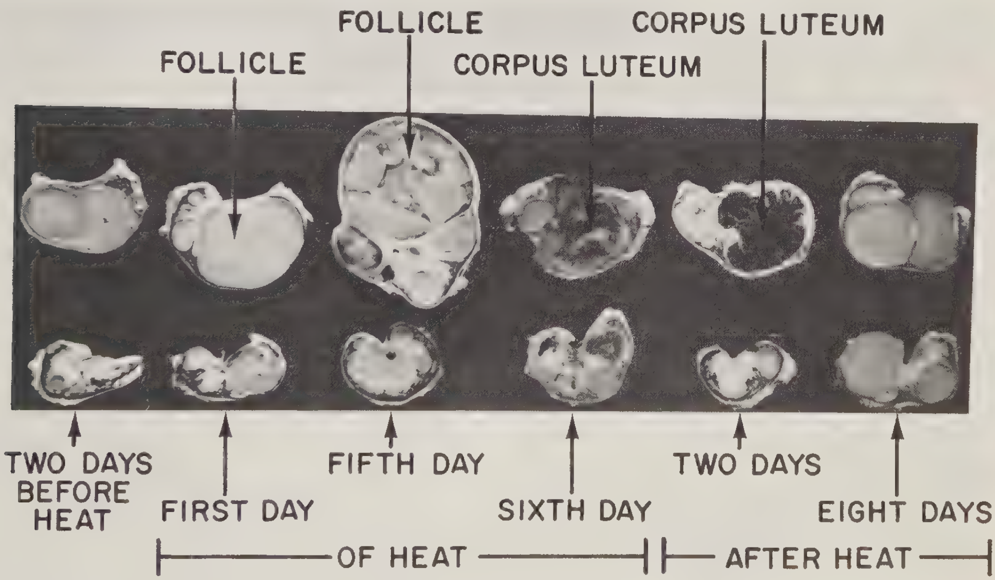



**FIGURE 5-11.** *Ovaries of mares at different stages of the heat cycle. The upper row of sections (or slices) are from an ovary that is currently active. The ovary from the mare in the fifth day of heat is full size. The follicle in the first half of heat usually feels tight, but, as ovulation time approaches, it becomes flaccid. The early corpus luteum that replaces the follicle at ovulation feels spongy. After a week it sinks from the surface of the ovary and is difficult to palpate through the rectum. The photograph shows the ovaries at approximately ½X actual size. For details on the mare ovary, see Andrews and McKenzie (1941). Courtesy of Sir John Hammond (deceased).*

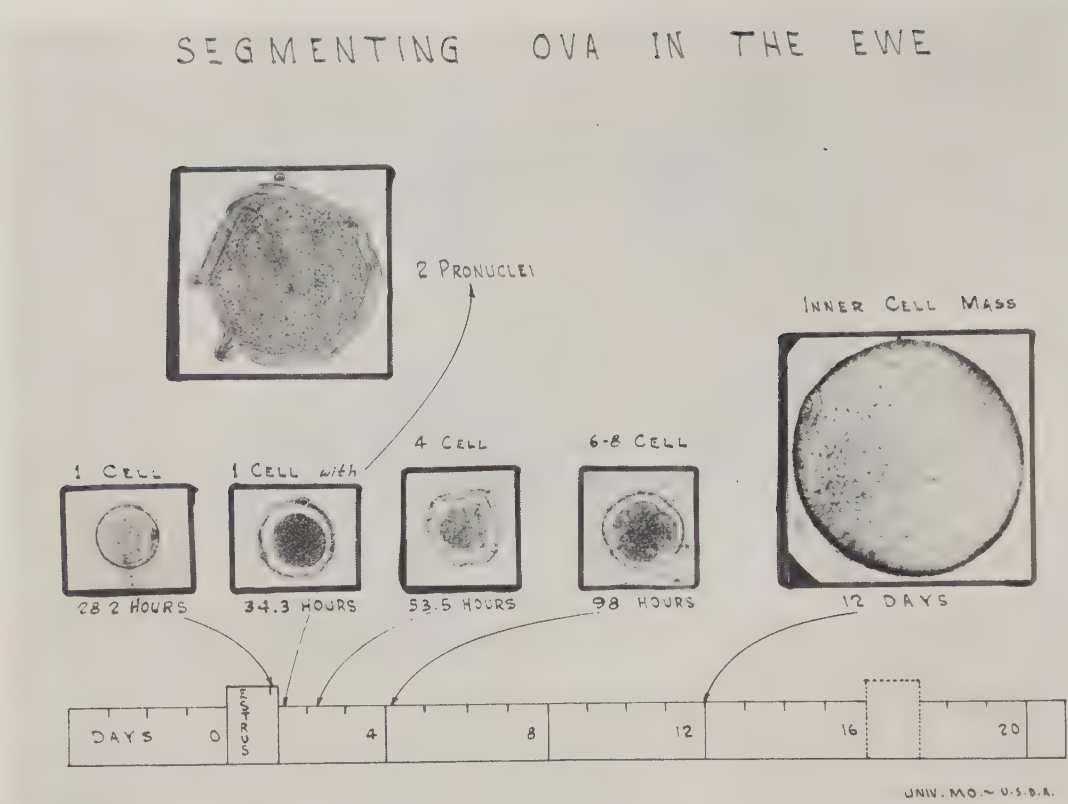



**FIGURE 5-12.** *Development of the fertilized egg in the ewe (female sheep). The sheep egg is fertilized immediately after ovulation, which occurs in late heat, and develops rapidly. Note that the section of the 34.3-hour specimen shows two pronuclei (one nucleus from the egg cell and another from the sperm cell) about to unite with each other. From McKenzie and Terrill (1937).*

therefore are the sites where ova and sperm meet and where fertilization takes place. The open end (funnel, infundibulum) of each oviduct is quite spacious so that the fertilized ova traverse it in a short time. However, for the ova to travel down the remaining two-thirds of the oviduct, 3 to 5 days are required in cows and ewes and probably about the same amount of time in other farm animals. From the oviduct, the newly developing embryos pass to the uterus and soon attach to it (Figure 5-12).

**Uterus.** The uterus (womb) varies in shape from the type that has long, slender left and right branches (horns), as in the sow, to the type that is mostly a fused body with very short branches, as in the mare. In the human, of course, the body of the uterus is even more predominant—so completely are the branches fused into one uterine body that the oviducts arise directly from the uterine body. It is in the body of the uterus that each embryo develops into a fetus and remains until parturition (birth). It is through the uterus that sperm must pass enroute to the upper ends of the oviducts, there to meet the ova.

The lower outlet of the uterus is the cervix, a muscular organ that constitutes a formidable gateway from the uterus to the vagina, and from the vagina to the uterus. Like the rest of the reproductive tract, the cervix is lined with mucosal cells. These cells change very much as the animal goes from one period of estrus to another, and they change in pregnancy, also. The cervical passage changes from one that is tightly closed or sealed in pregnancy, or nearly closed when the animal is not in heat, to a relatively open, very moist canal at the height of heat.

**Vagina.** The vagina serves as the organ of copulation at mating and as the birth canal at parturition. Its mucosal surface changes during the heat cycle from very moist when the animal is ready for mating to almost dry, even sticky, between periods of heat. The tract from the urinary bladder joins the posterior ventral vagina; from this juncture to the exterior vulva, the vagina (or vestibule) serves the double role of a passage for the reproductive and urinary systems (Figure 5-7).

**Clitoris.** A highly sensitive organ, the clitoris, which is located ventrally and at the lower tip of the vaginal vestibule, comes into prominence at mating time. Digital stroking of the clitoris speeds the ovulating mechanism and shortens the time from insemination to the moment of ovulation, another method by which management can influence reproduction in our farm animals. Digital stroking of the clitoris of the cow at the time of insemination causes the sperm to move faster to the fertilization site, increasing the likelihood of a healthy start for the new offspring (Figure 5-7). This increased speed of travel of some of the sperm through the uterus is brought about by the relatively strong peristalsis (muscular contraction) of that organ. The stimulation of the clitoris, whether through natural mating or through digital stroking, contributes to the increased activity of the uterus. Sperm find the environment in the upper oviduct the most stimulating physiologically and therefore the most exhausting. However, these sperm are constantly being augmented by sperm moving up from the lower tract where their surroundings have been somewhat less stimulating and hence more favorable to survival.

## What Makes the Testicles and Ovaries Operate

**In the male.** The testicles produce their hormones under stimuli coming to them from the anterior pituitary body (AP) situated at the base of the brain. The AP elaborates two hormones important to male performance, the luteinizing hormone (LH) and the follicle-stimulating hormone (FSH). LH produces its effect on the interstitial tissue of the testicle (probably the interstitial cells), causing this tissue to produce the male hormone testosterone. Indeed LH has been called the interstitial-cell-stimulating hormone (ICSH). LH and ICSH are the same chemically, but because the term LH was used first, that nomenclature has persisted. FSH stimulates cells in the seminiferous tubules to develop into functional spermatozoa.

Some species which respond to changes in length of day exhibit more seasonal fluctuation in reproductive activities than others. These influences are on the neurophysiological mechanism, the hypothalamus. The hypothalamus is the floor and part of the wall of the third ventricle of the brain and secretes releasing factors through portal vesicles that affect the anterior pituitary and its production of FSH and LH.

**In the female.** The mature female farm mammal does not experience the heat cycle if the ovaries are removed. If the substitute for the ovarian hormones estradiol and estrone is properly administered to a spayed (castrated) female, she shows all the signs of heat: (1) behavioral changes, and (2) changes in the reproductive tract that are characteristic of heat, namely, tone and structural changes, and mucus secretion. "Proper administration" of the hormones includes using dosages of

suitable potency and repeating the dosage over a period of time to allow for the thickening of tissue in the genital tract from the basic condition to that typical of heat.

Ovarian hormones in the entire, sexually mature female owe the rhythmicity of their production to hormones that originate in the anterior pituitary body and to the interplay between gonad-stimulating hormones produced there and ovarian hormones whose level and potency vary as the estrual (or estrous) cycle progresses. The follicle-stimulating hormone (FSH) circulates through the bloodstream and affects the responsive follicle cells of the ovary, which respond by secreting the so-called estrus-producing hormones, estradiol and estrone. When the amount of estradiol and estrone in the blood reaches a sufficient level, the pituitary is caused to reduce its production of FSH. With this drop in FSH production, the production of estradiol and estrone subsides, thus accounting for the rhythm. When the estrus-producing hormones have been lost from the body and their depressing effect on the anterior pituitary has been spent, the anterior pituitary again steps up its production of follicle-stimulating hormone and the cycle is repeated.

Luteal cells, the successors of the follicle cells, secrete a hormone called progesterone, which plays a role in the female reproductive cycle. Progesterone is involved in the occurrence and recurrence of the desire to mate, that is, the estrual cycle. Synchronized with this cycle is the important and essential phenomenon of ovulation. Ovulation occurs in the cow *after* estrus. It occurs in the sow, ewe, goat, and mare toward the latter part of, but nevertheless during, estrus. These species all ovulate spontaneously—that is, ovulation takes place whether copulation occurs or not. By contrast, copulation (or some such stimulation) is necessary to trigger ovulation in such animals as the rabbit, cat, ferret, and mink. Ovulation in these animals takes place at a fairly consistent time after mating.

What is the physiological basis for ovulation? The follicle of the ovary grows, matures, fills with fluid, and then softens some few hours before rupture. Note that rupture is not brought about by an increase in pressure to the point of bursting. The FSH of the anterior pituitary accounts for the increase in size of the ovarian follicle and for the increase in the amount of estrus-producing hormones (estradiol and estrone), which are products of the follicle cells. Now another part of the anterior pituitary elaborates the luteinizing hormone (LH), which alters the follicle cells and granulosa cells of the ovary, changing them into luteal cells. These luteal cells are in turn stimulated by luteotrophic hormone (LTH) from the anterior pituitary to produce progesterone.

When a certain delicate balance between high amounts of estrus-producing hormones and a minimal amount of progesterone is attained, the membranes over part of the large follicle thin out, separate, and break, thus allowing the follicular fluid to escape and carry the ovum into the open end of the oviduct. Thus, ovulation is accomplished. After the ovum escapes from the follicle, the hole through which it escaped is sealed over and the cells that formed the ruptured follicle are luteinized by LH. In the course of 7 to 10 days what was formerly an egg-containing follicle develops into a cell-filled, luteal body (the corpus luteum) of about the same size and shape as the mature follicle. The egg, having

escaped and migrated down the oviduct, is of course absent from the corpus luteum. The luteal cells of the corpus luteum produce a quantity of progesterone sufficient to depress the part of the anterior pituitary that produces FSH until the luteal cells reach maximum development (in nonpregnant animals), cease their development, and (in 3 weeks) lose their potency and disappear.

If pregnancy occurs, the corpus luteum continues to flourish, persists in its progesterone production, and prevents further ovarian cycles (estrus-producing cycles). Thus, no more heat occurs until after pregnancy has terminated.

What environmental factors influence the estrual cycle, the onset of pregnancy, and the seasonal fluctuations in male fertility? The changing length of day is a potent factor. Changing day length acts directly on the hypothalamus and indirectly on the animal by affecting plant growth, thus altering the quality and quantity of nutrition available. In cattle and horses, increasing length of day is associated with increased reproductive activity in both males and females. In sheep, the breeding season reaches its height in the autumn as the hours of daylight shorten. Of course, individuals of both sexes vary in their intensity and level of fertility. When selection has resulted in improvements in the traits associated with reproduction, individuals exhibit higher levels of fertility (that is, more intense expression of estrus, occurrence of estrus over more months of the year, and occurrence of spermatogenesis at a high level over more months of the year) than do unimproved breeds.

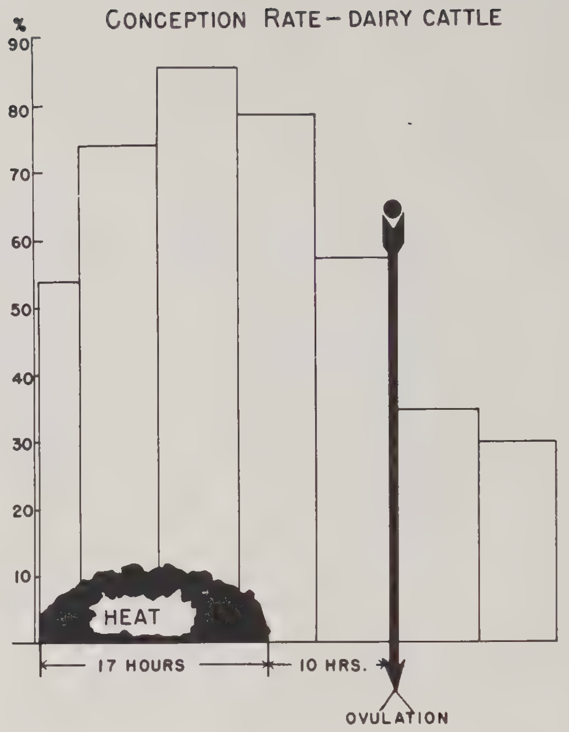
## Pregnancy

If conception occurs, pregnancy is initiated. The initial thickening of the wall of the uterus that precedes conception continues. In farm mammals, the new organism migrates through the oviduct to the uterus in 3 to 4 days. By then it has developed to the 16- or 32-cell stage. The chorionic and amniotic membranes develop about this new embryo and attach it to the uterus. The embryo (later the fetus) gets nutrition and discharges wastes through these membranes. This period of attachment (30th to 35th day of pregnancy in cattle) is critical. Unless the environment is sufficiently favorable, the embryo dies. Embryonic mortality causes a significant economic loss in farm animals. It is vital that management protect the female early in pregnancy by providing feed of sufficient quality and minimizing stress. The female should enter breeding season in a thrifty (vigorous), gaining condition and maintain this condition throughout the first weeks of pregnancy.

The embryonic stage in the life of an individual is defined as that period in which the body parts differentiate to the extent that the essential organs are formed. This period lasts 45 days in cattle. In a study done by this author (McKenzie and Terrill, 1937), eggs recovered from sheep 4 days or less after the onset of heat had already passed the 4-cell stage of division and development, and were still no larger than the unfertilized egg (diameter 150 to 200 $\mu$m). By 11 or 12 days after heat, the new individual had grown in size to three times the size of unfertilized eggs.

When the embryonic stage is completed, the young organism is called a fetus. The fetal period, which lasts until birth, is mainly a time of

**FIGURE 5-13.** *Is there a best time to breed the dairy cow? Dairy cows bred early in the heat period returned later for rebreeding more frequently than those bred or inseminated by the technician for a few hours after "standing" (when cows stand and allow mating) heat. Note the cow typically sheds her egg (ovulates) some 8 to 12 hours after heat.*




growth. The duration of gestation (pregnancy) in cattle is about 280 days; in swine, 114 days; in horses, 336 days; and in sheep, 147 days. The length of pregnancy varies, chiefly with the breed and the age of the mother.

Parturition (birth) marks the termination of pregnancy. The membranes that form around the embryo in early pregnancy and attach to the uterus are collectively called the placenta. This organ of pregnancy develops the capacity to produce hormones, namely, estrus-producing hormones (estrogens) and progesterone. A balance between estrogens and progesterones is attained in which the estrogens predominate in quantity. The uterine muscles become sensitive to the hormone oxytocin, which is produced by the posterior pituitary. Under the stimulus of oxytocin, the weak, rhythmic contractions of the uterus that prevail through most of pregnancy become pronounced and cause labor pains, and the parturition process is underway. Parturition is a synchronized process. The cervix, until now tightly closed, relaxes. The relaxation of the cervix, along with the pressure generated by the uterine muscles on the contents of the uterus, permits the passage of the mature fetus into the vagina and on to the exterior. Another hormone, relaxin, is thought to be a factor here. Relaxin, which originates in the corpus luteum or in the placenta, helps to relax cartilage and ligaments in the pelvic region to facilitate parturition.

At what points can one exercise effective control over a livestock operation? Critical times in livestock management include the times before and during the breeding season, the times of early and late pregnancy,

the times of parturition and early lactation, and the early weeks in the life of the newborn (Figure 5-13). The wise operator knows that attention to the stock, especially at these periods, has much to do with profits and success. For the reader who wishes to learn more about the critical times in livestock management, the listed references will be most helpful.

## Study Questions and Suggestions

1. How may one control livestock-breeding operations to make them more profitable?
2. What organs of the reproductive systems do the sperm traverse from the time they are freed to move about until they reach the ova?
3. What organs of the male contribute to the makeup of semen?
4. How does castration affect the anatomy and function of the reproductive organs of the bull?
5. Describe the epididymis of a farm mammal and explain how it contributes to fertility.
6. Trace the development of the cow's egg from its early beginning to the stage when it can be fertilized.
7. Do all eggs of our farm mammals develop and mature? If not, what happens to them?
8. Do all sperm of our farm mammals develop and fertilize eggs? If not, what happens to them?
9. How does the uterus of the cow contrast with that of the sow? With that of the mare?
10. What part in livestock reproduction efficiency does the clitoris play?
11. How can one explain the fact that an unbred sow, ewe, cow, or mare comes back into heat over and over again?
12. After an ovarian follicle ruptures and the egg escapes, what happens to this follicle?
13. Describe ovulation (what happens and why).
14. What in the environment influences the estrual cycle?
15. The successful management of a breeding herd depends much on the operator's attention and care given at certain critical times in the reproductive cycle. What are these critical times?

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# 6. Artificial Insemination (AI)—Fad or Fixture?

An activity which involves 7.3 million dairy cows of breeding age (48.6% of the United States breeding herd), which has grown to this figure in less than 40 years, and which accounts for maintaining the same volume of milk produced nationally by but half the number of cows that were required before the program began, *must* be significant—therefore artificial insemination (AI) of dairy cattle is a fixture most likely to survive as an integral part of our agricultural industry.

Artificial insemination involves the collection of semen from the male and the placement of some of that semen into the female genital tract. In this process the semen is usually evaluated, diluted ("extended") with a suitable medium, and preserved. Today the process has been developed and refined into one of the most effective means of improving cattle.

Geneticists have applied their skills to implement genuine improvement so that truly superior germ plasm is being created. The widespread use of such germ plasm by AI results in livestock measurably better than we have ever known and in numbers vast enough to have an impact on our economy.

Semen is collected from the bull by having him mount a cow (or a steer or another bull) and ejaculate into an artificial vagina (A.V.) device (Figure 6-1). Under good management, a bull can be trained to deliver semen on demand and to do so regularly. In exceptional cases semen can be obtained from a bull by stimulating him electrically to ejaculate. This procedure calls for an electric ejaculator device and a

This chapter was written by Dr. Fred F. McKenzie specially for this book.

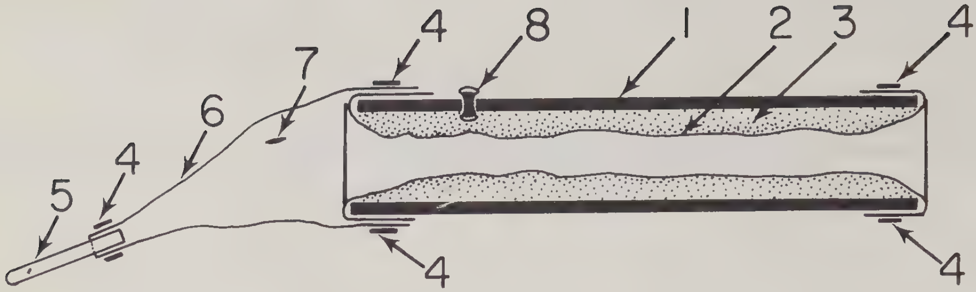


FIGURE 6-1. *Artificial vagina for cattle and water buffaloes: (1) thick outer casing 35 to 40 cm in length and 7 cm in diameter (similar to car radiator hoses); (2) thin rubber tubing or inner liner reflected over both ends of the outer casing, making a space to hold warm water (45°C to 50°C); (3) warm water; (4) rubber bands; (5) glass tube or vial that may be covered to protect it from light and cold (cover not shown); (6) thin rubber cone connecting casing to semen-collecting vial; (7) slit in cone to allow air to escape and to prevent ballooning.*

trained operator; it is not a routine method of obtaining semen. Semen is now so readily available by purchase from reputable cattle-breeding establishments that seldom does a cattle operator resort to semen collection, but, rather, buys the semen in frozen ampules, straws, or beads and has a technician place it in the cow.

Once spermatozoa are ejaculated and are hence limited to an ampule or other container, they no longer have the host animal's blood and lymph supply to nourish them and carry off their waste products. The addition of antibiotics to this dilutor environment along with buffers to stabilize the acid-base balance enhances the chances of the sperm cells retaining their fertilizing capacity. Subsequently the advantage of low (freezing) temperature was discovered. Frozen semen is now the "order of the day" in cattle insemination programs. With the protection from freezing that glycerol provides to living tissue, properly diluted bull semen cooled to -196°C (-320°F) survives for months and even for a year and more. Bull semen preserved in tanks that contain liquid nitrogen as the refrigerant is distributed commercially at monthly intervals to inseminating technicians. By contrast, before 1957 (when the use of liquid nitrogen became the accepted technique), it was necessary to provide a fresh supply of liquid semen every second or third day.

Thus semen from bulls selected to pass on desirable hereditary traits is available today from several reputable breeding associations. One no longer needs to collect semen from one's own bulls in order to carry on a good AI program. If one does wish to use semen from one's own bull for AI, an AI company can be called in to provide custom service—that is, collect, evaluate, process, preserve, and store semen from the bull.

## Optimum Time to Inseminate

Dilution of semen makes possible a greatly expanded use of a sire. For example, a bull ejaculates about 5 ml of semen (a teaspoonful). In natural breeding, one cow gets one whole ejaculate, and often a second, third, and more. Under an AI regime one good ejaculate can be diluted and preserved for later use on many (300 to 500) cows. One good ejaculate from a bull contains 4 to 5 billion sperm. Experience indicates that 12 million good sperm are enough for any one insemination of a cow. So why not divide the properly diluted and processed ejaculate into 300 to 500 parts?

A great deal of research has been done on the dilution, or extension, of semen. Still more research is needed. A dilutor should not only increase the volume—it should also aid in the preservation of the sperm cells. To what extent semen should be diluted depends on the concentra-

tion of the spermatozoa in the original semen ejaculate and on the breeding history of the sire. It is essential that one start with semen of high quality. No dilutor can make semen of poor quality into semen of good quality. A dilutor must be economical and fairly simple to prepare. The various ingredients must be readily available. Egg yolk-citrate dilutors and those made from boiled milk are the preferred dilutors of bull semen in the United States today.

Laboratory experience is required in order to properly prepare dilutors of semen. Precision, sanitation, and exacting care are "musts." The student who wishes to review the many details of preparation is referred to Herman and Madden (1974).

Cows are not capable of conceiving every day. Not only is the period when a cow will mate restricted, but there is also an optimum time for conception to take place. Under an AI regime the good manager will arrange to discover those cows that are receptive—that is, "in estrus" or "in heat" (each cow is "in heat" for only one day in its 18- to 24-day cycle of heat). To find these receptive females and inseminate them is the crux of an AI program. To fail here spells failure for the whole regime. To not breed cows when they can and should be bred means delayed breeding and means that animals are being held over to be fed and maintained for more days than necessary, with the result that costs increase. This inefficiency jeopardizes the success of the whole operation.

So find those females in heat. Observe females most carefully for the behaviorial signs of heat (restlessness, bawling, mounting, abandonment of calf, reduced milk flow) and the physical signs of heat (moist vulva, matted hair on rump, clear vaginal discharge), and arrange to handle the herd to afford the best likelihood of identifying these individuals. Almost any interested person can learn to do this.

Receptive cows may be singled out by allowing altered bulls to run with the herd so the bulls can mark receptive cows. Altering of the bulls should prevent copulation. A "marking" bull is made to wear an ink marker (of a color that contrasts to the colors of the cows) under his jaw so that when he mounts a cow to copulate, he leaves marks on the cow's back where his jaw rubs.

The AI programs involving dairy cattle differ from those involving beef cattle. Dairy cows are seen daily and can be watched closely. It may be necessary to turn them loose each day so that their behavior can be observed. Cows receptive to mounting are in heat. On the beef cattle ranch, one has to make the effort to see the breeding herd daily. It is best to see the herd early each morning and late evening, because, whereas the herd is relatively quiet at these times, restless cows in heat often separate from the others. The cows in heat can then be segregated and taken to the insemination quarters for breeding.

Insemination equipment consists of a syringe adapted to accommodate the kind of semen container being used. Semen containers are ampules, plastic straws, and beads. Using the syringe, the technician can deposit the 0.5 to 1.0 ml of diluted semen through the cervix of the cow into the uterus (or nearly so). This necessitates grasping the cervix with one's gloved hand inside the rectum of the cow and manipulating the cervix so that the inseminating tube may enter the cervix (or neck of the womb), allowing the semen to be deposited in the anterior cervix and uterus proper.

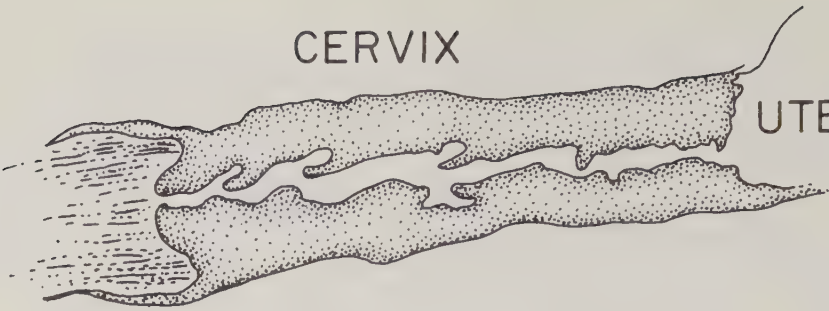


**FIGURE 6-2.** *The cervix of the cow (actual size) showing the three or four transverse folds that make it difficult to pass a tube through the rectal wall with thumb and one or two fingers unless one has practice in manipulating the cervix. The hand grasping the cervix should push forward, thus stretching the vagina and straightening and aligning the cervix. The other hand should put only mild forward pressure on the plastic tube. The tube should never be forced, for to do so damages the tissue.*

Putting the semen-containing tube through the cervix of the cow is difficult at first. It can be learned with practice. Proper manipulation of the cervix with the hand in the rectum involves grasping the cervix area and carefully threading the cervix over the tube. Note that the cervix is made to move over the tube—the tube is *not* pushed through the cervix. Figure 6-2 illustrates the irregular surface of the cervix and the pockets into which the tube may enter. *Do not force the tube.* (If the tube is pushed hard enough when in a "blind alley," it could break through the wall of the tract and enter the peritoneum. Such an accident is not likely to occur if the technician is skilled.)

## Checking Results

By observing cows for signs of heat and keeping a record of those that show heat, one can identify the cows that do not return to heat. These cows are assumed to be pregnant, or "settled." The percentage of cattle that do not return to heat is the figure that measures the effectiveness of the inseminator and permits the herd owner to assess that inseminator's level of success. Whenever the percentage figure is below optimum, the owner can make adjustments for improvement before it is too late.

Artificial insemination in species other than cattle is not widespread in the United States. The chief obstacle is that the technology of semen preservation is lacking. Of course, semen can be collected and used fresh in horses, swine, sheep, and goats, and this is done to some extent (see Figures 6-3, 6-4, 6-5, 6-6, 6-7, and 6-8). In the United States, 85% to 90% of all breeding female turkeys are artificially inseminated with fresh semen. The combination of improvement in semen preservation techniques and the availability of highly selected, genetically attractive sires of these species will insure increased acceptance of AI because the method will then become economically feasible.

The AI technology today has reached a truly advanced state. This is particularly true where cattle are involved. One of the really great contributions of AI to the cattle-breeding industry is the reduction of risk of disease. Bulls are screened with the greatest care in terms of their health before being permitted to be used in an AI program. The semen to be used is diluted with antibiotics which minimize the chance that any organism present in the semen will damage it. Not only is the health of the cows inseminated with such semen wonderfully protected, but the bulls are spared exposure to infected cows. Prevention of disease is one of the great assets in AI. Diseases such as vaginitis, brucellosis, tuberculosis, leptospirosis, vibriosis, Johne's Disease, and trichomoniasis are

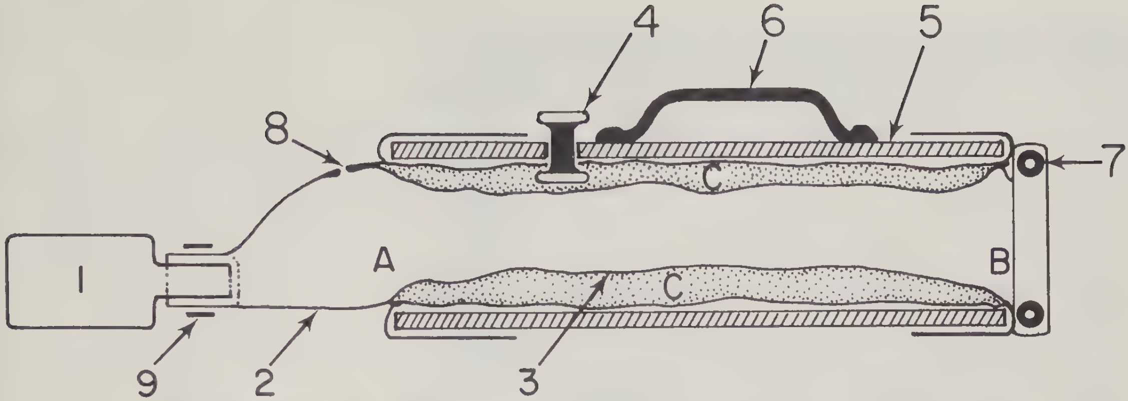


**FIGURE 6-3.** *Artificial vagina for horses, designed and used by Fred F. McKenzie: (1) 250-ml bottle in which semen is collected; (2) rubber tubing, 17.5 cm in flat diameter by 45 cm in length, exclusive of the tapering part fitted to the bottle – this tubing makes a water jacket that accommodates the penis and affords a suitably warm temperature; (3) similar rubber tubing welded (or vulcanized) at points A and B to form a water-holding area, C; (4) valve, 1 cm in diameter, through which are passed 2 to 3 liters of water of 50°C from water-holding area; (5) thick leather casing, with handle, surrounding the rubber tubing; (6) handle; (7) ring of garden hose, 2 cm in diameter, which serves to hold open the entrance end; (8) slit in rubber to allow air to escape when A.V. is in use; (9) rubber band.*

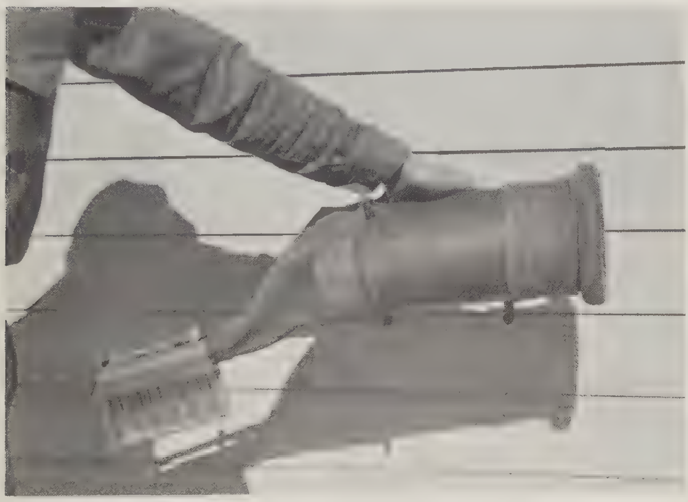

**FIGURE 6-4.** *The artificial vagina for the horse or jack. It is light enough in weight to be held by one hand. Instead of the 250-ml bottle for semen collection, this model uses the battery of vials shown to learn in what sequence sperm are ejaculated. The first portion of semen passed (5 to 10 ml) is watery and gray, and contains very few sperm. The second fraction (25 to 75 ml) is thin, or watery, in consistency and has a high sperm concentration (50,000 to 400,000 or more sperm per* $mm^3$*). The third portion ejaculated is viscous, and, if present at all, is usually the largest fraction (44% to 71% of the total ejaculate). It is called the gel. It is not present in the autumn in stallions, and is rarely ever present in jacks. From unpublished data by Fred F. McKenzie.*

**FIGURE 6-5.** *Grade Belgian filly dropped April 25, 1940, out of Irma (dropped 1935), who was bred May 25, 1939, on U.S. Range Livestock Experiment Station, Miles City, Montana, 20 hours after the semen used was collected from Belgian stallion Rowdy, Animal Husbandry Experiment Station, USDA, Beltsville, Maryland. The semen was carried 2,000 miles by airplane.*

FIGURE 6-6. *Teaser ram fitted with apron to prevent copulation when he mounts and marks a ewe. The chalk or paint used for marking is between his front legs. Ewes in heat are marked by teaser rams. The ewes are then brought to one place and inseminated.*

FIGURE 6-7. *Mare in teasing chute with her foal kept in plain view. To learn whether a mare is in heat, a stallion is brought near her to see if she is receptive to his approaches. If she has a foal, the foal should be kept where she can see it. Otherwise the mare may grow so anxious about her foal that she does not show her true response to the stallion, thereby masking her reaction to his presence. Strong poles of the chute placed near a solid wall minimize the danger that the mare will kick someone.*



FIGURE 6-8. *Semen is evaluated by microscopic examination. Any semen collected for use is observed for motility, concentration, and normality of its sperm cells. The sperm in Figure 6-8A appear normal in shape. Those in Figure 6-8B are misshapen and some are without tails. The sperm in specimen A could be expected to come from semen that is good in quality. The sperm in specimen B is definitely from semen that is low in quality. From sheep, 1500X. Courtesy of Dr. Arthur S. H. Wu, Oregon State University.*

thus kept to a minimum. Such diseases are rarely heard of in well-operated AI regimes.

In contrast to the 25 to 75 cows per year bred to a bull under natural breeding, AI organizations regularly breed more than 3,000 cows annually to a single bull; many bulls artificially inseminate 40,000 to 50,000 cows in a year. The cost to the cow owner runs \$6 to \$10 per cow in the United States and usually includes two repeat inseminations if needed. This rate of cost includes the use of semen from most of the best bulls.

## Other Possibilities

When females can be reliably induced to come into heat and ovulate, management will move to inseminate larger numbers, be they cows, mares, or females of any other species.

It would be helpful to be able to induce estrus and to bring about ovulation so that animals may be inseminated at chosen times. The success of such a program depends on whether conception follows insemination and whether pregnancy proceeds to full term with normal parturition and subsequent lactation occurring.

Scientists have labored for more than 20 years to synchronize estrus and ovulation. Progesterones, natural and synthetic, have been used with less than satisfactory results—10% to 45% calving in cattle. Now prostoglandin $F_2$ (a naturally occurring, hydroxylated, unsaturated fatty acid) shows some promise with cattle and sheep. This substance must be used only from the midluteal phase of the heat cycle onward. Heat is induced about 3 days after administration, and ovulation follows another day later. Intramuscular dosages administered to cows have consisted of 30 mg; intrauterine dosages, 5 mg. Cows so treated have thus far compared favorably in fertility with control animals that did not receive prostoglandin $F_2$.

An increase in the intensity of breeding carries with it the demand for increased attention to nutrition and handling of the animals being bred in order to provide the optimum environment for the reproductive system to operate. Just as the male can be handled (managed) by AI to exceed his natural limits, it is here forecast that we shall learn to manage the worthy female so that she can exceed her natural number of offspring by threefold or more by transplanting fertilized ova from one cow to the uterus of another, thus avoiding subsequent overcrowding of fetuses that can cause prenatal mortality. Although increasing the number of offspring from a given female may not find widespread application on our farms, its implementation could accelerate the production of genetically superior offspring from selected females. Already a few commercial laboratories have undertaken the recovery of fertilized ova from highly selected cows and heifers and implanted these into recipient heifers in which uterine development has been successful in many cases and has resulted in normal births (embryo transplantation). This procedure is expensive as of now. More general use awaits simpler techniques.

The reader is referred to Chapter 5 for further details pertinent to semen amount, frequency of ejaculation, time of ovulation, and length

of estrus or heat in different species, and how these factors are related to fertility.

For the many details of the technique of semen collection and preservation and the actual insemination of the female, one should consult the list of references below.

## Study Questions and Suggestions

1. How does one collect semen from a bull?
2. What are the signs of heat, or estrus, in a cow?
3. Are livestock in an AI program less exposed to health hazards than livestock that breed naturally?
4. In what way is the system of AI for beef cattle different from that for dairy cattle?
5. AI is not carried on extensively in the United States with sheep, swine, and horses. Why?

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# 7. Growth—How Animals Become Larger and How They Mature

Growth is a complex phenomenon and any definition of it is likely to be inadequate. Growth begins shortly after the egg is fertilized and continues until the animal reaches its mature size.

## Definition of Growth

Growth has been defined as an increase in protoplasm (living material in the cell) in excess of the destruction or loss of protoplasm. If this definition is accepted, increases in such things as fat, water, and bone are not counted as growth. Perhaps growth could be defined as the amount of protein that is synthesized over the amount lost. By this definition, growth is accomplished through cell multiplication, through increases in cell size, or through a combination of both. Fattening, bone deposition, and water storage in the tissues, each of which can be increased or decreased at any time in postnatal life, is not considered as growth. However, it is extremely difficult to actually measure what percentage of an animal is stored fat, water, and bone. The increase in weight that occurs with time in young animals is considered to be growth because rapidly gaining animals do not store large quantities of fat and the percentage of bone in an animal is not high.

## Measuring Growth

Growth is not a straight-line function regardless of how it is expressed mathematically. If one considers growth as an increase in mass

FIGURE 7-1. *A generalized graph of growth of mammals from conception to maturity.*


(weight), the growth curve is somewhat S-shaped in that it starts at a slow rate, accelerates at a very rapid rate, and then slows markedly. The S-shaped growth curve is illustrated in Figure 7-1. It has been found that the shape of this growth curve applies to all farm mammals even though actual weights in different species are quite different.

The general mathematical description of growth as an increase in weight with time is: Growth $= \frac{w}{t}$, in which w = weight and t = time. The mathematical description of the rate at which an animal gains weight during a particular period of time is: Rate of gain $= \frac{\Delta w}{t}$, in which $\Delta$w = the change in weight that occurred in the time period involved ( $\Delta$ = "change in") and t = time. For cattle in the postweaning period, weight is expressed mathematically as a straight line because the cattle gain weight at a constant rate throughout this period. However, the rate of gain declines as the animal increases in age and approaches puberty, and growth ceases when the animal reaches maturity. If one wishes to describe growth as weight increase per unit of body weight as time changes, the equation is: Growth per unit of body weight $= \frac{\Delta w/w}{t}$, in which $\Delta$w = change in weight, w = initial weight, and t = time. The rate of increase in weight per unit of body weight always declines as time changes.

## Factors Affecting Growth

Growth rate is influenced by both external and internal factors. The most important external factor is nutrition; animals that do not receive a sufficient quantity of food and those fed an improper diet do not grow well. Two important internal factors are inheritance and endocrine, or hormonal, secretions. (It is likely that endocrine function is also under genetic control but endocrine function and inheritance will be discussed separately.) Postweaning rate of gain in farm animals exhibits strong

genetic control, but the inheritance of growth is not simple. It appears that the maximum potential for growth of an animal is inherited, but whether the animal approaches this maximum depends greatly on its environment. Even with the best rations that scientists have been able to develop, some animals grow at a much slower rate than others. These differences in rate of growth are under strong genetic control. Endocrine glands are ductless glands which produce hormones that are secreted into the blood. A hormone is a chemical secretion from an endocrine gland that is carried by the bloodstream to other parts of the body where it exerts a specific effect. Although most of the endocrine glands contribute directly or indirectly to growth, the most important glands affecting growth are the pituitary, thyroid, ovaries, testes, and adrenals.

The pituitary gland is located under the brain, posterior to the optic chiasma. It produces several hormones, the most important to growth being somatotropin (growth hormone). Growth hormone stimulates nitrogen retention and results in true growth—more protein synthesis than protein loss. Administration of growth hormone increases growth over a short period of time, but it cannot be continued with success. The growth hormone is a protein, and repeated injections of it cause the animal to develop antihormone substances and antibodies. Thus, the injection of growth hormone not only becomes ineffective but may also cause anaphalactic shock (the antibodies developed as a result of injecting a foreign protein cause the injected protein to be coagulated, and this coagulation may result in death).

The thyroid gland consists of two lobes, one on each side of the trachea (windpipe), which are connected by an isthmus. The thyroid secretes the hormone thyroxine, which controls body metabolism. The effects of thyroxine differ from those of some hormones in that either an insufficiency or an excess is harmful. Insufficient thyroxine in early life results in disproportionate dwarfism, with greater development of the head and shoulders than of the posterior part of the body. In later life, insufficient thyroxine results in a harsh coat of dry hair, lethargy, and storage of large amounts of subcutaneous fat. An excess of thyroxine causes the animal to grow less rapidly than normal, because the animal is literally burning itself up due to an excessive rate of metabolism. In this situation the catabolic, or destructive, metabolic action becomes greater than the anabolic, or constructive, metabolic action.

The function of the thyroid gland is influenced by thyrotrophic hormone (which is secreted by the pituitary gland), by iodine intake in the diet, and by environmental temperature. If the diet is low in iodine, the thyroid gland cannot produce sufficient thyroxine. When denied sufficient iodine, the thyroid continues to be stimulated by the pituitary, increases in size, and develops into a goiter (Figure 7-2). Goiter development can be prevented by supplying iodized salt.

The ovaries produce progesterone and estrogens. One of the effects of progesterone is to increase protein retention or synthesis; it is, therefore, a growth stimulant. The growth-stimulating effect of progesterone may provide one explanation of why pregnancy is a stimulant to the female. Estrogenic effects vary with species. For example, the administration of estrogens reduces growth in rats, increases fattening in chickens, and increases growth and decreases fattening in cattle and sheep.

FIGURE 7-2. *Goiter in newborn lambs resulting from an iodine deficiency in the ration of the mother. Courtesy of Dr. J. H. Landers, Oregon Agricultural Extension Service.*

The administration of a synthetic estrogenlike substance, diethylstilbestrol (DES), to feedlot steers and wether (castrated male) lambs results in increased gains, in decreased feed required per unit of gain, and in carcasses that are relatively high in lean and low in fat. Diethylstilbestrol has been administered either in the feed or as an implant in the ear so that any portion remaining in the body at slaughter is discarded. It is possible that DES may be banned by the Food and Drug Administration even though its use appears to be safe when proper usage is employed. Animals given DES in the feed must have the feed containing the DES removed from the ration for a sufficient length of time prior to slaughter to assure that all DES has been eliminated from the animal's system.

Synovex, a combination of substances containing estrogen and progesterone, has been used in ruminant animals to stimulate rate and efficiency of gains. Ralgrow, a substance obtained from fungus, stimulates rate and efficiency of gains in a manner similar to DES but reportedly has no estrogenic properties. Rumensin (also called Monensin) is an antibiotic against coccidia (organisms that cause the disease called coccidiosis), but it has also been found to alter the ratio of volatile fatty acids in the rumen in such a way as to lead to increased rate of gain. Ralgrow and Rumensin may come into widespread use if DES is banned.

The testicles produce testosterone and other androgenic (masculinizing) substances. Androgens stimulate growth, reduce feed required per unit of gain, and help form carcasses that are relatively high in lean and low in fat. Androgens have a much greater stimulating effect on females than on castrated males. It is interesting to note that in most farm animals, including cattle, sheep, goats, fowl, and pigs, males grow more rapidly and reach larger adult size than females. (Rabbits are an exception—female rabbits reach considerably heavier weights at maturity than males.) The question may arise: "If males grow rapidly because of testosterone production, what effect will castration have?" Castration of young male calves, lambs, and pigs results in reduced growth. Castrated

animals are easier to handle, and in pigs castration prevents the unsavory flavor of meat that otherwise develops in boars. The price paid for intact males for slaughter is lower than for castrated animals of comparable quality. Spaying (castration) of female farm animals does not appear to influence growth. Spaying of heifers and implanting Synovex H* in them gives increased growth.

The adrenal glands are located anteriorly and medially to the kidneys. Each consists of two parts, the medulla and the cortex. The medulla, or center part, of the adrenal gland produces the hormone adrenalin. The cortex, or outer part, secretes many steroids. Some of these steroids regulate electrolysis and water metabolism; others influence protein, carbohydrate, and fat metabolism. Administration of cortisone (one of the steroids produced by the adrenal cortex) to cattle and sheep causes an increase in body fat. Animals having hyperadrenal activity often become obese.

## Phases of Growth in Farm Animals

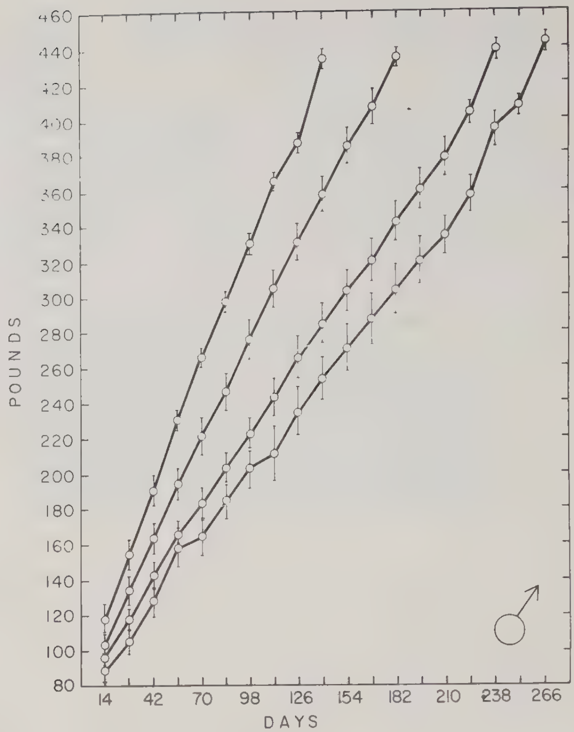
Growth has thus far been discussed in a general way. Actually, three phases of growth occur in farm mammals and each phase has specific influences affecting it. The three growth phases are (1) prenatal, (2) preweaning (but postnatal), and (3) postweaning.

**Prenatal growth.** In animals that produce several young at one time (multiparous), prenatal (before birth) growth is influenced by the number of fetuses present in the uterus of the pregnant female. High numbers may result in insufficient nourishment to the individual fetuses, causing small young to be born. In animals that produce only one young (monoparous), the size and the age of the mother influences prenatal growth of the young. Young females and small females that are mature usually have smaller offspring than older and larger females because of differences in uterine environment, such as the size of the uterus. In addition, the birth weights of calves of beef cattle vary significantly with the sire, indicating that inheritance plays a significant role in prenatal growth.

**Preweaning growth.** The growth of young animals in the preweaning (nursing) period is highly influenced by the quality and quantity of the milk provided by the mother. When very large litters of pigs are produced by a sow, she may be unable to produce sufficient milk for optimal growth for all of them. In sheep, twin lambs usually grow less rapidly than single lambs. Research has shown that twin lambs grow slower due to the lack of sufficient milk for optimal growth for both. Although a ewe nursing twins gives more milk than one nursing a single lamb, she does not produce double the quantity.

The preweaning weights of bull calves that were weighed each 14 days from birth until they reached a weaning weight of at least 425 lbs. vary much more for those requiring a long time to reach the given weight than for those reaching the weight in a short time (Figure 7-3). It appears that some calves grow continuously at a rapid rate, some grow continuously at a slow rate, and some gain both rapidly and slowly at various times in the preweaning period. Growth during the preweaning period is computed as follows:

FIGURE 7-3. *Preweaning weights of rapidly and slowly gaining male calves plotted by 2-week periods showing the standard deviation (a measure of the amount of variation) at each weighing period. The sample sizes for the data lines plotted from left (fastest gains) to right (slowest gains) are, respectively, 30, 50, 50, and 30.*




$$\text{Preweaning rate of gain} = \frac{\text{weight at weaning - weight at birth}}{\text{days from birth to weaning}}$$

Beef cattle producers often object to the use of rate of gain to weaning because the rate is expressed in decimals and small figures. Methods have been developed for computing weight at the age of 205 days, which is the average age at weaning (when milk from the mother is replaced by other foods) of range calves that were used to develop this method of adjusting weight of calves at weaning to a common age:

$$\text{Weight at 205 days} = \frac{\text{weight at weaning - weight at birth}}{\text{days from birth to weaning}} \times 205 + \text{weight at birth}$$

If birth weight has not been recorded, an average birth weight of 70 lbs. is often used for the computation. The figures expressing 205-day weights are rounded to whole numbers, and some people find them more usable than figures expressing weight gains per day.

Young females, aged females, and females of small mature size within a breed usually produce less milk than large, mature females. The amount of milk available to the offspring affects preweaning growth. When food is not available in sufficient quality or quantity, females produce less milk and thereby reduce preweaning growth of their young. When females that are capable of producing a satisfactory amount of milk are given favorable feeding conditions in which to nurse calves, intact males usually grow more rapidly than castrated males and castrated males grow more rapidly than females during the nursing period. When feeding conditions are not good, there is little difference in preweaning growth of male and female young.

The effects of age of dam (female parent) and sex of the young on growth are shown most strikingly in cattle and sheep. Calves from 2-year-old cows are about 75 lbs. lower in weaning weight at about 7 months of age than calves from mature cows. Also, male calves from cows on a good pasture or range are usually about 40 lbs. heavier than females at a weaning age of 7 months. Male lambs are usually 3 to 5 lbs. heavier than females at 100 to 120 days of age. Male pigs are only slightly (not more than 3 lbs.) heavier than females when weaned at 56 days of age. Apparently, the effects of male hormones are relatively less when animals are weaned at relatively young ages.

**Postweaning growth.** Postweaning growth of cattle is growth that occurs between weaning and slaughter weight of 1,000 to 1,100 lbs. To compute rate of gain during the postweaning period, one uses the following equation:

$$\text{Postweaning rate of gain} = \frac{\text{final weight - weight at weaning}}{\text{days from weaning to final weight}}$$

This equation can also be used for computing postweaning gains of pigs and lambs. Any differences of postweaning rate of gain among farm animals are largely under genetic control, providing that the animals are not subjected to variations in food supply such as exists while they are nursing.

Several other factors may influence postweaning rate of gain. Animals that were under austere feed conditions during the nursing period because their dam did not provide sufficient milk for them tend to compensate when they are weaned and are given better feed conditions, provided that the earlier austere conditions were not severe enough to cause permanent damage. By contrast, young that were nursed by a dam that gave an abundance of milk may find feed conditions following weaning less satisfactory than what they enjoyed while they were with their dams. Such young tend to grow less rapidly during the initial phase following weaning. Although animals tend to compensate for previous austerity, they do not overtake, in total weight, those young that had better feed conditions previously at a given age. Thus, one cannot expect to use compensatory gains as a means of marketing more weight of animals in a given time period. Animals that gain more rapidly in the feedlot require less feed to make a unit of gain than slowly gaining animals. They also store more lean and less fat in their bodies. Thus, rapidly gaining animals resemble relatively young animals physiologically whereas slowly gaining animals resemble relatively old animals.

When intact male and female animals reach puberty and begin to develop sexually, their growth rates decline even though growth continues for some time after puberty is reached. For example, beef bulls such as Herefords reach puberty at about 15 months, at which time they weigh 1,200 lbs. or more. They continue to grow for another 25 months, and may eventually reach 1,800 to 2,700 lbs. Growth rate declines continually from puberty until maturity is reached, at which time growth ceases entirely.

Males grow more rapidly than females during the postweaning period even though they eat no more feed per unit of body weight than

females; consequently, males make their gains with much less feed per unit of gain than females. Rapidly gaining bulls, for example, may gain 3.5 to 4.0 lbs. per day and may require 5.0 to 5.5 lbs. of feed per lb. of gain, whereas rapidly gaining heifers may gain 2.7 to 3.0 lbs. per day and may require 6.5 to 8.0 lbs. of feed per lb. of gain.

## Maturity

After an animal reaches maturity, it may change in weight by a considerable amount simply by increasing or decreasing the amount of fat that it stores. The increase in weight of a mature animal due to fattening is not growth because no net increase in body protein occurs. In fact, animals tend to lose body protein as they grow older. The loss of body protein in an animal is one of the phenomena in the aging process.

As most mammals reach maturity, a closure of the epiphyseal-diaphaseal junction occurs. This junction is between the shaft and the joint end of the long bones. Growth of long bones takes place in the cartilage at this junction, but after it is closed by bone formation (ossification), no further growth can take place. The epiphyseal-diaphaseal junction appears to close in all farm mammals. In the rat, as a contrasting example, the epiphyseal-diaphaseal junction never closes; consequently, one can initiate growth in mature (even old) rats by injecting growth hormones. No growth can be initiated by injecting growth hormones into mature cattle, sheep, or swine.

## Study Questions and Suggestions

1. a. Define growth.
   b. If growth is expressed as weight according to age, what type of growth curve is obtained?
   c. What is the appearance of the curve that expresses gain in weight per unit of time during the rapidly gaining period of growth?
   d. If the growth of an animal is expressed as change in weight per unit of body weight per unit of time, what is the appearance of the growth curve?
   e. After animals become mature, they may gain considerably in weight. Is this growth?
2. a. If growth is explained on a cellular basis, how is growth defined?
   b. What hormones affect growth? Where are these hormones produced?
   c. Males usually grow more rapidly than females. What effect does this relatively rapid rate of growth have on percentages of lean and fat in their carcasses? What effect does it have on the efficiency of gains?
   d. Can growth in farm animals be increased over long periods by injecting growth hormone? Why?
   e. Can growth in mature farm animals be initiated by injecting growth hormone? Why?
3. a. Diethylstilbestrol (a synthetic estrogen), when fed or injected, causes ruminants to react one way, chickens to react another

way, and rats to react a third way. What are the reactions of each?

b. What factors influence prenatal growth of farm animals?
c. What factors greatly influence preweaning growth of farm animals? Which is the most important?
d. In which of the postnatal periods (preweaning or postweaning) is growth most under genetic control?
e. What is the relationship of rate of growth to percentages of lean and fat of the body?

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# 9. How Animals Adapt to Their Environment

With regard to the maintenance of body temperature, there are two kinds of animals; those that are *poikilothermic*, or cold-blooded, and those that are *homeothermic*, or warm-blooded.

The body temperature of poikilothermic animals varies with environmental temperature and is approximately equal to the temperature of the environment. The body temperature of homeothermic animals is maintained at a uniform temperature that is characteristic of the species. Thus, the body temperature of homeothermic animals may be much above that of the environment in cold periods and somewhat below that of the environment when the weather is hot.

The body temperature of homeotherms usually varies from 98°F to 105°F and death will occur if environmental temperatures should become excessively high or low for any appreciable length of time unless the animal is capable of adapting. All farm animals are homeothermic; therefore, the discussion to follow will deal only with homeothermic animals, and mammals, rather than poultry, will be emphasized.

## Heat Production in Animals

The routine body processes and physiological processes of farm animals, such as digestion and assimilation, rumen fermentation by protozoa and bacteria, cellular activity, muscular activity, growth, and milk production, produce a great amount of heat. Thus, most animals, after they pass the stages that directly follow birth, are concerned more with dissipation of heat than with keeping warm. Animals on full feed,

such as those in feedlots, have difficulty eliminating heat unless the environmental temperature is 40°F or more below the body temperature.

The metabolic rate of very young animals is low, and it does not increase until they obtain food and generate heat through the work of digestion and assimilation. Very young animals may be chilled and succumb when the temperature is cold, because they are wet when they are born and evaporation of the moisture on them increases the cooling effect of the temperature. If born in cold weather, the young should be wiped dry and encouraged to nurse almost immediately; it may also be necessary to provide some type of heat for the newborn.

## How Heat Is Dissipated by Animals

Animals may be cooled by convection (air currents) if the environmental temperature is below that of the body. If the surface of the animal is wet, air currents increase evaporation and thus help cool the animal even if environmental temperature is higher than the animal's body temperature. Evaporation is more pronounced if the air is dry than if considerable moisture is in the air. Thus, when humidity is low, evaporation is much greater than when humidity is high.

Some animals, such as horses, perspire, and this perspiration provides moisture on the body surface. Such animals are cooled greatly from evaporation when the air is dry. Other animals, such as sheep, hogs, dogs, and some cattle, may lack the ability to sweat except at the nose. Their greatest source of cooling through evaporation is their lungs. Inhaling dry air and exhaling moist air provides considerable cooling; this is one reason why animals such as dogs pant when the weather becomes quite warm or after strenuous exercise.

When the surface of the animal is wet, wind velocity and humidity of the air produce significant cooling effects. A wet animal on a windy day loses much more heat than either a dry animal that is exposed to wind or a wet animal that is not exposed to wind.

Heat also radiates from the surface of an animal. Therefore, the amount of body surface affects the amount of cooling available to an animal. Brahman cattle, which have a large skin surface per unit of body weight, are more capable of withstanding hot climates than some of the cattle which have less body surface per unit of weight. Heat may also be lost through conduction (movement through a conducting medium). An animal lying on concrete or iron, both of which are good heat conductors, will lose more heat than an animal lying on wood, shavings, or sawdust.

The amount and kind of fibers growing from the surface of animals influence heat loss, and the fibers may act as insulation. The hair of horses and cattle grows longer as the weather cools in the autumn and winter, and is shed in the spring or early summer as the temperature of the environment increases. Pigs do not grow a thick coat of hair, but they do lay down a thick layer of fat immediately under the skin which prevents excessive heat loss.

## Adjusting to Environmental Changes

To summarize heat production and heat loss in animals, one notes that heat is generated by digestion, assimilation, fermentation (in rumi-

nants), cellular activity, muscular activity, growth, and milk production. Heat from solar (sun) radiation can also be absorbed by the body. Heat loss occurs through convection, radiation, conduction, and evaporation. We now have information to understand how animals may adapt to temperature changes in their environment.

As the seasons change, two major kinds of changes occur in the environment: changes in temperature and changes in length of daylight. As summer approaches, temperature and length of daylight increase, thus increasing the amount of heat from the environment that is available to the animal. As autumn approaches, length of daylight and temperature decrease. The animal has two mechanisms for coping with the changing seasons. First, it may grow an insulating coat (wool or hair) as the temperature decreases and shed this insulation when the temperature increases. Second, an animal may alter its metabolic rate as the temperature changes.

The thyroid gland, whose lobes are located on either side of the trachea (windpipe), regulates the metabolic activity of the animal. In times when the environmental temperature is cool, the cool air that is inhaled tends to cool the thyroid gland. The thyroid responds by producing and secreting more thyroxine; the thyroxine, in turn, stimulates metabolic activity, thus generating more body heat. As the temperature increases, warm air is inhaled, warming the thyroid gland. Warming the thyroid gland causes it to reduce its output of thyroxine, which consequently reduces metabolic activity and decreases the amount of heat generated by the animal. The thyroid acts slowly; consequently, sudden changes in temperature will be felt by the animal. The growing and shedding of insulating coats are also slow changes that are influenced by hormones. Sudden warm periods before the animal has shed and sudden cold periods before a warm coat has been produced can be severe for an animal. These sudden temperature changes are the greatest predisposers for the development of respiratory diseases.

## The Effect of Altitude on Animals

Animals accustomed to a low altitude have some difficulty when placed in a high altitude. As altitude increases, temperature and oxygen content of the air decrease. Generally, animals exercise more when the temperature is low than when it is high. Exercise generates more heat, but it also requires more oxygen for oxidative processes that generate heat. Exercise at high altitudes leads to physiological difficulties because more oxygen is needed but less is available. The animal can slowly but effectively adjust, within limits, to high altitudes by increasing the number and concentration of red blood cells and hemoglobin. This adjustment creates a more effective oxygen-carrying mechanism that compensates for the lower oxygen content in the air.

## Macroclimate and Microclimate

To cope with the stresses of the macroclimate, animals can create or use an effective microclimate for comfort and survival. Some desert animals go into holes in the ground during the heat of the day to occupy a microclimate that is much cooler than the macroclimate. People create microclimates by wearing clothes and by living in buildings

which are heated or air conditioned, and which keep out rain, snow, and direct sunlight. People also use artificial light. Sometimes animals are also provided microclimates in the form of shelters to keep out rain and snow, windbreaks to prevent excessive air convection, and, in the case of young animals, heat that is provided.

In some cases, excessive heat may be prevented by providing shade. A sprinkler system may be used to provide moisture on the surface of animals and air currents may be generated by fans to help animals that sweat when the weather is hot. Sprinklers in combination with shade are particularly helpful in dry climates because of the cooling effect that evaporation of moisture has on wet skin.

## Temperature Zones of Comfort and Stress

The comfort zone, or zone of thermoneutrality, is 60°F to 65°F for animals; in this range of temperature, heat production, and heat loss by animals are about the same. When the temperature is between 0°F and 50°F, animals increase their feed intake, exercise more, increase their rate of heartbeat, and reduce blood flow to the surface and to the extremities. Animals may shiver, which is a form of exercise that generates heat. Birds fluff their feathers to create a large space of dead air about themselves to prevent rapid heat transfer from their bodies. Other animals may "hunch up" in order to expose less body surface. Sometimes, animals will get close together so each can make use of heat from others (Figure 9-1). Getting close together can lead to "piling up" and death if it is carried to an extreme.

Animals have a unique way of maintaining the temperature of their extremities at a level below that of the body. Heat loss from the extremities is reduced if the extremities are at a relatively low temperature. Blood pumped from the heart flows through arteries to the extremities, and blood from the extremities flows through veins back to the heart. The arteries and veins are in close proximity. Therefore, the warm blood from the heart warms the blood that is coming to the heart from the veins, thus preventing cold blood from being delivered to the heart. The cold blood from the extremities cools the warmer arterial blood so that the extremities are kept at a cool temperature. This whole process of heat exchange between arteries and veins is called countercurrent blood flow action.

Between 65°F and 80°F, dilation of blood vessels near the skin and in the extremities occurs so that the surface of the animal becomes warmer, water consumption increases, respiration increases, and, in animals that can sweat, perspiration increases. Above 85°F animals that have the capacity to sweat keep their body surfaces wet with sweat so that evaporation can help cool them. Nonsweating animals respire rapidly (pant) and are cooled by evaporation in the lung tissues. When the environmental temperature exceeds 90°F, animals suffer. Hogs may die from such heat. Animals tend to become less active, and they usually lie down in the shade. Reduced activity decreases the amount of heat that is generated and lying in the shade reduces the effects of solar radiation. Water consumption and urine excretion increase, and if the water consumed is cooler than the temperature of the animal, considerable cooling can occur.

**FIGURE 9-1.** *A Charolais calf and a cat share heat that each generates for keeping warm. From Litton Charolais Ranch.* Charolais Bull-o-gram. *Chillicothe, Mo.: Litton Charolais Ranch. February-March 1975. Copyright © 1974.*

Sometimes animals must adapt to food or water shortages. Fat-tailed sheep and Brahman cattle store large quantities of fat that may be called upon as a source of energy if food becomes scarce over a short duration. Animals that eat lush growths of forages may only need to drink water once each day or once every other day, whereas animals that are eating dry feeds need water at frequent intervals.

When animals do work, there is a marked increase in the amount of heat that is produced. Animals on full feed produce a great deal of heat in performing digestion and assimilation. The dairy cow that is producing a large quantity of milk may produce two to three times the heat that is produced by a nonlactating cow of the same size. She has to consume large amounts of food in order to produce large quantities of milk. In addition, much work is required for the production of milk, which also produces heat. Animals used for work, either for pulling loads or for riding, produce a great deal of heat. All animals that are generating large quantities of heat are more adversely affected by hot weather than by cold weather.

## Inability of Animals to Cope with Heat at Times

Sometimes animals are unable to control their body temperature. Young animals may become chilled, and their body temperature may go

below normal; thus, some external source of heat is often needed for young animals when the weather is cold. Also, animals may at times lack the capacity to dissipate enough heat to maintain normal body temperature.

When the body temperature of an animal exceeds normal because the animal cannot dissipate its heat, a condition known as fever results. Fever is often caused by systemic infectious diseases. Fevers often are most severe when environmental temperatures are extremely high or low. Keeping the ill animal as comfortable as possible while medication is given will assist the animal to recover. When the temperature becomes excessively high, some animals (notably pigs) may lose normal control of their senses and do things that aggravate the situation. If nothing is done to prevent them from doing so, pigs that get too hot will often run up and down a fence line, squealing, until they collapse and die. If one sees a pig doing this, one should put water on the pig to help cool it, and get it to lie down on the wet soil surface so that it will become quiet.

## Study Questions and Suggestions

1. a. By what mechanisms may an animal lose heat?
   b. By what mechanisms may an animal conserve heat?
   c. Why is a very young animal more influenced by cold temperatures than when it is older and larger?
   d. An animal on full feed has a problem eliminating heat. Why?
   e. What are the body processes that generate heat?
2. a. Define homeotherm and poikilotherm. To which of these classes do farm animals belong?
   b. What is the zone of thermoneutrality?
   c. When temperatures are below 50°F, what does an animal do initially to keep warm? What can one do to assist an animal in keeping warm?
   d. What physiological changes occur in an animal when it is subjected for a long time to a low temperature?
   e. What physiological changes occur in an animal when it is subjected for a long time to high altitudes?
3. a. How can animals be assisted to remain cool when the weather is hot?
   b. What effect does circulating the air about an animal that does not sweat have on cooling the animal?
   c. When an animal's body surface is wet, what effect do air currents have?
   d. Is heat conservation or heat elimination more important in animals that are producing large quantities or milk?
   e. What happens to an animal's temperature when disease-causing organisms invade the body?

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# 10. How Feeds Are Digested and Absorbed

Animals obtain substances needed for all body functions from the feeds they eat and the liquids they drink. The feeds supplied cannot be absorbed as such; consequently, feed that is eaten must undergo preparation for absorption through the process called *digestion.* Digestion includes mechanical forces such as chewing and contractions of the intestinal tract; chemical action such as the secretion of hydrochloric acid in the stomach and bile in the small intestine; and enzymatic action, through enzymes that are either produced by the various parts of the digestive tract or by microorganisms. The effect of digestion is to reduce the size of molecules so that they may be absorbed.

## Carnivorous, Omnivorous, and Herbivorous Animals

Animals are classed as carnivores, omnivores, and herbivores according to the types of feed that they normally eat. Carnivores, such as dogs and cats, normally consume animal tissue as their source of nutrients; omnivores, such as humans and pigs, consume both plant and animal tissues; herbivores, such as cattle, sheep, and goats, consume plant tissues. The carnivores and omnivores are monogastric animals, meaning that the stomach is simple and has only one compartment. Some herbivores, such as guinea pigs, horses, and rabbits, are herbivores and also monogastric. Other herbivores, such as cattle, sheep, and goats, are ruminant animals, meaning that the stomach is complex and contains four compartments. The classification of animals as carnivores, omnivores, and herbivores does not mean that they cannot use certain

feeds that they do not normally consume. For example, animal products can be fed to herbivorous ruminants, and certain cereal products can be fed to carnivores.

The digestive tracts of pigs and people are similar in anatomy and physiology; therefore, much, though not all, of the information gained from studies on pig nutrition and digestive physiology can be applied to the human. Both the pig and the human are omnivores and both are monogastric animals. Therefore, neither pigs nor humans can synthesize the B-complex vitamins or amino acids. Both pigs and humans tend to eat large quantities and to become obese. Humans can control obesity by exercising as a means of using, rather than storing, excess energy. Also, humans can control their food intake as a means of preventing obesity, whereas pigs eat freely as long as feed is available.

## Digestive Tract of the Pig—A Monogastric Animal

The anatomy of the digestive tract varies greatly from one species of animal to another. In a mammal having a simple stomach (such as the pig), the mouth has teeth and lips for grasping and holding feed that is masticated (chewed), and salivary glands that secrete saliva for moistening feed so it can be swallowed. Feed passes from the mouth to the stomach through the esophagus. A sphincter (valve) is at the junction of the stomach and esophagus. It can prevent feed from coming up the esophagus when stomach contractions occur. The stomach empties its contents into that portion of the small intestine known as the duodenum. The pyloric sphincter, located at the junction of the stomach and the duodenum, can be closed to prevent feed from moving into or out of the stomach. Feed goes from the duodenum to the jejunum portion and then to the ileum portion of the small intestine. It then passes from the small intestine to the large intestine, or colon. The ileo-cecal valve, located at the junction of the small intestine and the colon, prevents material in the large intestine from moving back into the small intestine. The small intestine actually empties into the side of the colon near, but not at, the anterior end of the colon. The blind anterior end of the colon is the cecum, or, in some cases, the vermiform appendix. The large intestine empties into the rectum. Material from the rectum passes to the outside through the anus. The anus has a sphincter, which is under voluntary control so that defecation can be prevented by the animal until it actively engages in defecation. The structures of the digestive system of the pig are shown in Figure 10-1.

## Digestive Tracts of Other Monogastric Animals

The type of digestive tract described above is known as monogastric because the stomach is simple and composed of only one part. Animals such as pigs, horses, rabbits, and poultry are classed as monogastric animals, but they differ markedly in certain ways. For example, the rabbit (Figure 10-2) and the horse have large cecal structures in which much fermentation occurs. Because the cecum is posterior to the area where most feed is absorbed, horses and rabbits do not obtain all of the material made by microorganisms in the cecum unless they eat their own feces. Rabbits are known to eat their feces regularly, and horses eat their

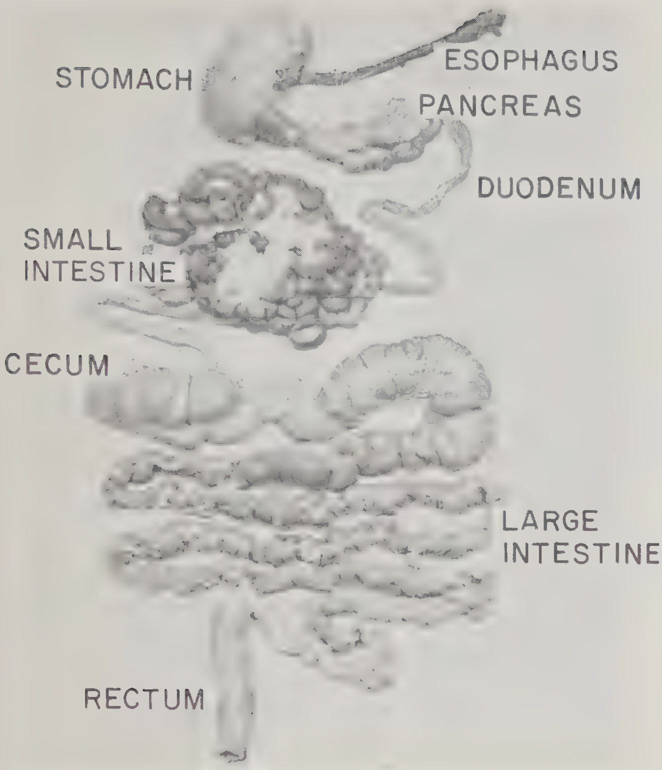


**FIGURE 10-1**. *Digestive tract of the pig as an example of the digestive tract of a monograstric animal. By permission of Dr. D. C. Church, from Church, D. C., and Pond, W. G.* Basic Animal Nutrition and Feeding. *Corvallis, Oreg.: Published by D. C. Church. Copyright © 1974.*

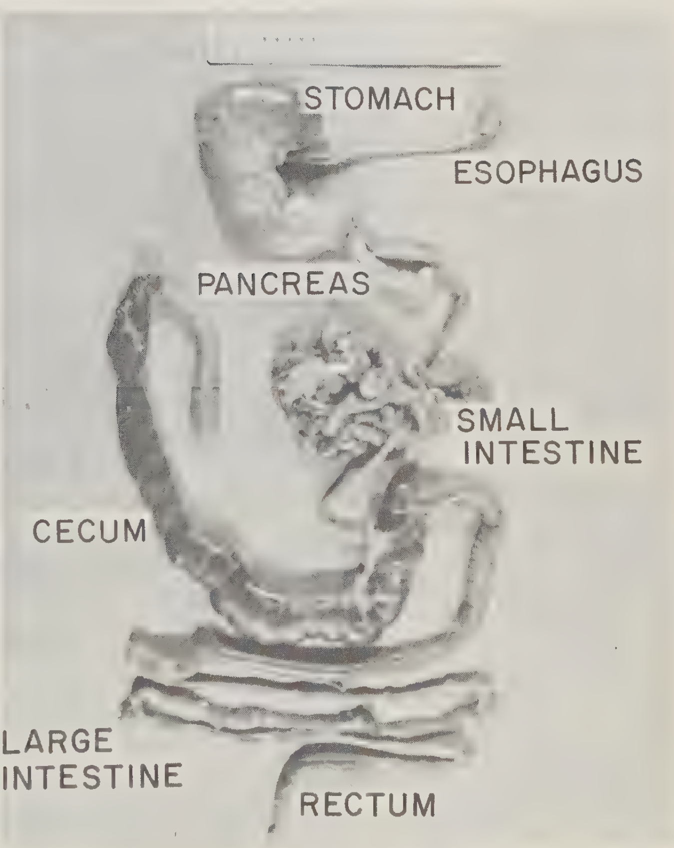


**FIGURE 10-2**. *Digestive tract of the rabbit, a monogastric animal with highly developed ceca where fermentation occurs. By permission of Dr. D. C. Church, from Church, D. C., and Pond, W. G.* Basic Animal Nutrition and Feeding. *Corvallis, Oreg.: Published by D. C. Church. Copyright © 1974.*

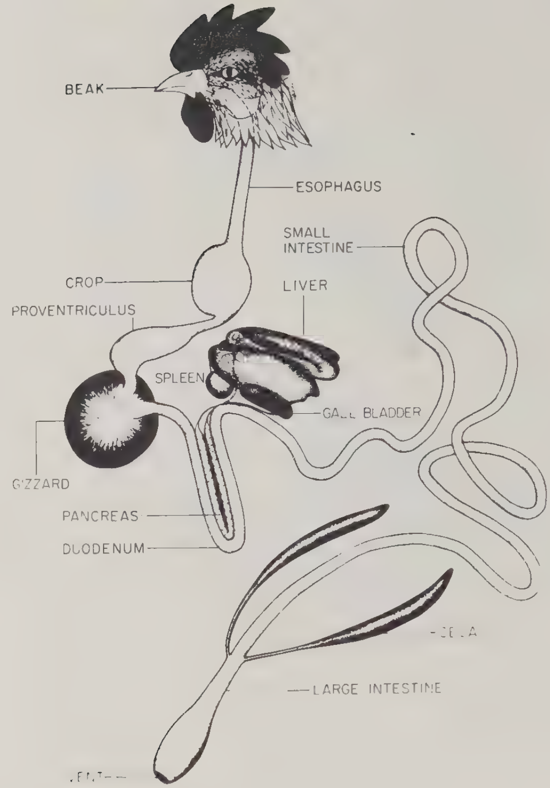


**FIGURE 10-3.** *Digestive tract of the chicken showing crop, proventriculus, and gizzard, all of which are characteristic of poultry. Drawing courtesy of Dr. J. E. Parker, Poultry Science Department, Oregon State University. Photograph by Dr. R. W. Henderson, Oregon Agricultural Experiment Station.*

feces when they are on diets of low-quality roughage and need some of the nutrients in the feces.

The digestive tracts of most species of farm poultry differ from that of the pig in several respects. Because they have no teeth, poultry birds break their feed into a size that can be swallowed by pecking with their beaks or by scratching with their feet. Feed goes from the mouth through the esophagus to the crop, which is an enlargement of the esophagus in which feed can be stored. Some fermentation may occur in the crop, but it does not act as a fermentation vat. Feed passes from the crop to the proventriculus, which is a glandular stomach in birds that secretes gastric juices and hydrochloric acid (HCl) but does not grind feed. Feed then goes to the gizzard, where it is ground into finer particles by strong muscular contractions. The gizzard apparently has no function other than to reduce the size of feed particles, because it can be removed without interfering with digestion if birds are fed a finely ground ration. Feed moves from the gizzard into the small intestine. Material from the small intestine empties into the large intestine. At the junction of the small and large intestines are two ceca which contribute little to digestion. Material passes from the large intestine into the cloaca, into which urine also empties. Material from the cloaca is voided through the vent (Figure 10-3).

## Stomach Compartments of Ruminant Animals

In contrast to the single, unitary stomachs of the monogastric animals, the stomachs of cattle, sheep, and goats have four compartments—rumen, reticulum, omasum, and abomasum. The rumen is a

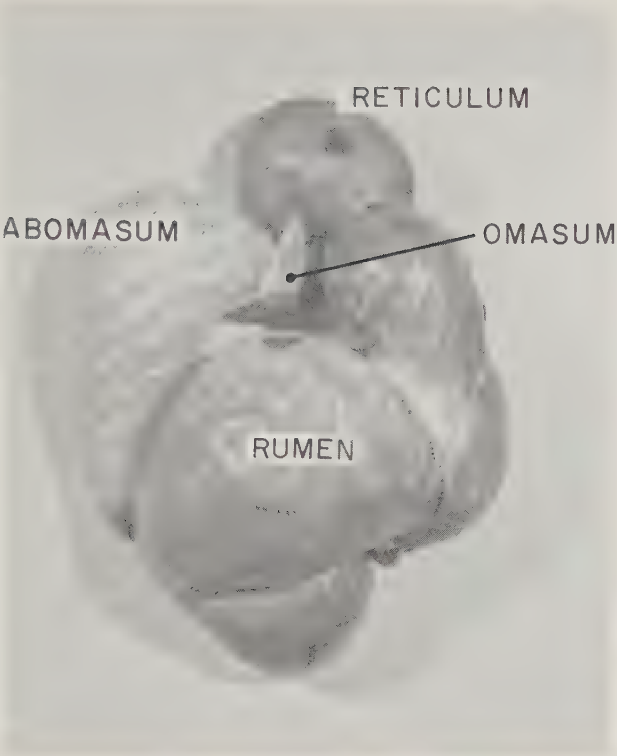


**FIGURE 10-4.** *The four compartments of the stomach of the sheep, an animal in which pregastric fermentation occurs.*

large fermentation vat where bacteria and protozoa thrive and break down roughages to obtain nutrients for their use. It is lined with numerous papillae, which gives it the appearance of being covered with a thick coat of short projections. The papillae increase the surface area of the rumen lining. The reticulum has a lining with small compartments similar to a honeycomb, so it is often called the honeycomb portion. The omasum has many folds, so it is often called the manyply portion. The abomasum, or true stomach, corresponds to the stomach of monogastric animals.

Animals that have the four-compartment stomach (Figure 10-4) eat forage rapidly and later leisurely regurgitate it and chew it again. The regurgitation and chewing of undigested feed is known as rumination. Animals that ruminate are known as ruminants. As feeds are fermented by microorganisms in the rumen, large amounts of gases (chiefly methane and carbon dioxide) are produced. The animal normally can eliminate the gases by belching, a process known as eruction of gases. If gases are not eliminated by eruction, bloating occurs; the rumen and reticulum expand drastically when bloated.

## Digestion in Monogastric Animals

Feed that is ingested (taken into the mouth) stimulates the secretion of saliva. Chewing reduces the size of the ingested particles and saliva moistens the feed. The enzyme amylase, which is present in saliva, acts on starch and dextrins in monogastric animals. However, very little actual breakdown of starch into simpler compounds occurs in the mouth, primarily because feed is there for but a short time.

An *enzyme* is an organic catalyst that speeds a chemical reaction without being altered by the reaction. Enzymes are rather "specific"; that is, each type of enzyme acts on only one or a few types of substances. Therefore, it is customary to name enzymes by giving the name of the substance acted upon and adding the suffix "-ase," which, by convention, indicates that the molecules so named are enzymes. For example, lipase is an enzyme that acts upon lipids (fats); maltase is an enzyme that acts upon maltose to convert it into two molecules of glucose; lactase is an enzyme that acts upon lactose to convert it into one molecule of glucose and one molecule of galactose; and sucrase is an enzyme that acts upon sucrose to convert it into one molecule of glucose and one molecule of fructose. Some lipase is present in saliva but no great amount of hydrolysis of lipids into fatty acids and glycerides occurs in the mouth.

As soon as it is masticated and moistened by saliva, feed is swallowed and passes through the esophagus to the stomach. The stomach secretes HCl, mucus, and the digestive enzymes pepsin and gastrin. The strongly acidic environment in the stomach favors the action of pepsin. Pepsin breaks proteins down into polypeptides. The HCl also assists in coagulation, or curdling, of milk. Little hydrolysis of proteins into amino acids occurs in the stomach. Mucous secretions help to protect the stomach lining from the action of strong acids.

In the stomach, feed is mixed well and some digestion occurs; this mixture is called chyme. The chyme passes next into the duodenum, where secretions from the pancreas, bile, and enzymes from the intestine are mixed with the chyme.

Secretion from the pancreas and discharge of bile from the gall bladder are stimulated by secretin, pancreozymin, and cholecystokinin, three hormones that are released from the duodenal cells. The enzymes from the pancreas are lipase, which hydrolyzes fats into fatty acids and glycerides; trypsin, which acts upon proteins and polypeptides to reduce them to small peptides; chymotrypsin, which acts upon peptides to produce amino acids; and amylase, which breaks starch down to disaccharides, after which the disaccharides are broken down to monosaccharides. The liver produces bile which helps emulsify fats; the bile is strongly alkaline and so helps to neutralize the acid material coming from the stomach. Some minerals that are important in digestion also occur in bile.

By the time they reach the small intestine, amino acids, fatty acids, and monosaccharides are all available for absorption. Thus, the small intestine is the most important area for both digestion and absorption of feed. Absorption of feed molecules may be either passive or active. Passive passage results from diffusion, which is the movement of molecules from a region of high concentration of those molecules to a region of low concentration. Active transport of molecules across the intestinal wall may be accomplished through a process in which cells of the intestinal lining engulf the molecules and then actively transport these molecules to either the bloodstream or to the lymph. Energy is expended in accomplishing the active transport of molecules across the gut wall.

When molecules of digested feed enter the capillaries of the blood system, they are carried directly to the liver. Molecules may go to the

lymphatic system and pass directly to the heart, after which they go to various parts of the body including the liver. The liver is an extremely important organ both for metabolizing useful substances and for detoxifying harmful ones.

## Digestion in Ruminant Animals

In ruminant animals (cattle, sheep, and goats), predigestive fermentation of feed occurs in the rumen and the reticulum. The bacteria and protozoa in the rumen use the roughages consumed by the animal as feed for their growth and multiplication; consequently, billions of these microorganisms develop. The environment of the rumen is ideal for the microorganisms in that moisture, a warm temperature, and a constant supply of feed are present. Excesses of microorganisms are continuously removed along with the feed that passes into the abomasum. When the feed passes into the abomasum, strong acids destroy the bacteria and protozoa. The ruminant animal then digests the microorganisms and uses them as a source of nutrients. Thus, ruminant animals and microorganisms mutually benefit from one another. All digestive processes in ruminants are the same as those in monogastric animals after the feed reaches the abomasum, which corresponds to the stomach of monogastric animals.

A young ruminant does not consume roughages. Consequently, at this stage in its life it acts as a monogastric animal. Milk is directed immediately into the abomasum in young ruminants. When roughage is consumed, it is directed into the rumen where bacteria and protozoa break it down into simple form for their use. The rumen starts to develop functionally as soon as roughage enters the rumen, but some time is required before it is completely functional. Complete development of the rumen, reticulum, and abomasum requires about 2 months in sheep and about 8 months in cattle. One can influence the development of the rumen by the type of feed given the animal. If only milk and concentrated feeds are given, the rumen shows little development. If very young ruminants are forced to live on forage materials, the rumen develops much more rapidly. "Roughages" and "concentrated feeds" are defined and discussed in Chapter 11.

## Pregastric and Postgastric Fermentation

In some animals, such as the rabbit and the horse, postgastric (cecal) fermentation of roughages occurs. In these animals, all the feed that can be digested by a monogastric animal is digested and absorbed before the remainder reaches the cecum. These animals are perhaps more efficient than ruminants in their use of feeds such as concentrates that can be digested. In the ruminant animals, the concentrates given along with roughages are used by the bacteria and protozoa. Because the microorganisms in ruminants use starches and sugars, little glucose is available to ruminants for absorption. The microorganisms do provide volatile fatty acids, which are absorbed by the ruminant and used in place of glucose as an energy source. The postgastric fermentation that occurs in horses and rabbits breaks down roughages, but this takes place posterior to the areas where nutrients are actively absorbed; conse-

quently, all of the nutrients in the feed are not obtained by the animal in postgastric fermentation. Postgastric fermentation is less efficient in the use of roughages than pregastric fermentation.

The large intestine functions primarily as a passageway for waste that is to be eliminated, and for absorption of water. Not much nutrient transport takes place across the wall of the colon.

The primary function of all parts of the digestive system anterior to the small intestine is the reduction in particle size of the feed. After the feed reaches the small intestine in birds, digestion proceeds in a fashion similar to that of ruminants.

## Study Questions and Suggestions

1. You should learn the parts of the digestive tract of a monogastric animal such as the pig. How does the anatomy of the digestive tract of the pig differ from that of the rabbit, chicken, and horse?
2. a. What are the four compartments of a ruminant stomach?
   b. In which compartments of the ruminant stomach does fermentation occur?
   c. Which part of the ruminant stomach is comparable to the stomach of the monogastric animal?
   d. What is meant by pregastric and postgastric fermentation?
3. a. What enzymes are produced by the stomach and upon what substances do they act?
   b. What function does hydrochloric acid produced by the stomach perform in digestion?
   c. What is digestion?
   d. What are the functions of bile?
   e. What enzymes are produced by the pancreas and upon what substances do they act?
4. a. What enzymes are produced by the small intestine and upon what substances do they act?
   b. Where does most absorption of nutrients occur and into what systems do absorbed nutrients go?
   c. What is absorbed from the large intestine?
   d. By what methods may molecules pass across the intestinal wall?
   e. What is the function of the cecum?

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# 11. The Functions of Nutrients in Simple-Stomached and Ruminant Animals

There are two classifications of animal feeds: concentrates and roughages.

*Concentrates* include cereal grains (corn, wheat, barley, and milo), oil meals (soybean oil meal, linseed oil meal, and cotton seed oil meal), fish meal, packing house by-products (tankage, meat scraps, liver meal), molasses, and dried milk products. They are high in energy, low in fiber, and highly digestible.

*Roughages* include legume hays, grass hays, straws from the production of grass seed and grain, silage, stovers (dried corn, cane, or milo stalks and leaves with grain portion removed), and soilage (cut green feeds). Roughages are less digestible than concentrates. Roughages are typically 50% to 65% digestible, but the digestibility of some straws is drastically lower. Concentrates are typically 80% to 90% digestible. Young animals do not have the capacity to consume enough low-quality roughage to achieve normal growth. Dairy cows are also unable to consume low-quality roughage in sufficient quantity to supply the nurtients required for high-level milk production.

## Nutrients and Their Functions

A *nutrient* is a chemical substance, in either mineral or compound form, which is absorbed from the digestive tract and travels through the bloodstream to all parts of the body for use in metabolism. Thus, protein as such is not a nutrient, but its components, the amino acids, are

nutrients. Nutrients that can be supplied only through the diet are called essential nutrients.

Monogastric animals require more essential nutrients than ruminants, because many nutrients can be made by microorganisms (bacteria and protozoa) in the rumen of ruminants. These microorganisms are absent in monogastric animals. Protein can be made from nonprotein nitrogen by microorganisms in the rumen. All of the B-complex vitamins can be made in the rumen, as can all of the amino acids if elemental or compound forms of nitrogen, sulphur, and carbon are present. By contrast, monogastric animals must obtain all of these nutrients, with the exception of some amino acids, from their feed.

Some amino acids are provided in abundance when sufficient protein is eaten, but certain amino acids are quite limited in many sources of protein. Thus, monogastric animals may have difficulty obtaining relatively scarce amino acids that they cannot synthesize. Some amino acids (glutamic acid, aspartic acid, alanine, and others) can be synthesized by monogastric animals if carbon, hydrogen, oxygen, and nitrogen are available in the metabolic pool. However, some either cannot by synthesized at all (histidine, lysine, threonine, and others) or are produced so slowly that they must be provided in feed (phenylalanine, methionine, tryptophan, and others). Amino acids of the latter two groups are called essential amino acids. All amino acids are needed by all animals, but whether they are "essential" or "nonessential" is determined by whether or not they must be supplied through the diet. The shortage of any particular amino acid can prevent an animal from using other amino acids for needed functions. A protein deficiency results.

**Protein.** The building blocks for growth (including growth of muscle, bone, and connective tissue), milk production, and cellular and tissue repair are amino acids that come from protein in feed. The interstitial (between cells) fluid, blood, and lymph require amino acids to regulate body water and to transport oxygen and carbon dioxide. All enzymes are proteins, so amino acids are also required for enzyme production.

Proteins are, on the average, 16% nitrogen. Knowing this allows us to calculate the amount or percent of protein in a feed if we know how much nitrogen is present in a given quantity of the feed. Because 16% into 100% = 6.25, we can multiply the amount of nitrogen by 6.25 to obtain the amount of protein present. If, for example, a feed is 3% nitrogen, 100 g of the feed contains 3 g of nitrogen. Multiplying 6.25 x 3 gives 18.75, meaning that 100 g of this feed contains 18.75 g of protein. Or, multiplying .03 x 6.25 gives .1875, which, when multiplied by 100 to give percent, tells us that the feed is 18.75% protein.

In analyses of feeds, the percent of nitrogen is determined chemically and the percent of protein in the feed is determined in the manner just described. The estimate thus obtained of the amount of protein in the feed may be too high because feeds may contain an appreciable amount of nonprotein nitrogen. The presence of a large amount of nonprotein nitrogen and a relatively small amount of protein in the feed is quite detrimental to the nutrition of monogastric animals because they cannot use some of the nonprotein nitrogen.

Rations in which the amount of protein present has been overestimated due to the presence of nonprotein nitrogen could likely be successfully developed for ruminants because ruminants can utilize non-

protein nitrogen quite efficiently. In fact, such sources of nitrogen as urea are often used to provide a portion of the protein needs for ruminant animals. This procedure is perfectly satisfactory so long as only a portion of the protein needs are supplied by urea—animals do poorly or may not survive when urea is the only source of protein. Some cattle have been raised with urea as the only protein (nitrogen) source and cows raised on urea as a protein source have produced calves. However, it is generally advised not to use urea at a level in excess of 50% of the protein needs.

The digestibility of protein is obtained by measuring .the nitrogen consumed and the nitrogen in the feces. Protein digestibility, expressed as a percentage, is calculated as follows:

$$\frac{\text{Nitrogen consumed - nitrogen in feces}}{\text{nitrogen consumed}} \times 100 = \%\ \text{protein digestibility}$$

**Carbohydrates and Fats.** The primary function of both carbohydrates and fats is to provide energy for the animal. Energy is the force, or power, that is used to drive a variety of systems. It can be used as motive power of the animal but most of it is used as chemical energy to drive reactions necessary to convert feed into animal products and to keep the animal warm. The unit of measurement of energy is the calorie. A calorie is the amount of heat required to raise the temperature of 1 g of water 1°C from 14°C to 15°C. It is a very small amount; therefore, most nutritional expressions are in kilocalories (1 kcal = 1,000 calories) or megacalories (1 mcal = 100,000 calories). Some express kilocalories as Kcal and other use Calories (abbreviated Cal) to designate kilocalories.

Carbohydrates are absorbed into the body from the small intestine as monosaccharides. Animals appear to readily derive energy from all of the common monosaccharides. Fats are absorbed into the body as fatty acids and glycerides. The energy that is available to the animal from the feed eaten depends on carbons that can be oxidized. As measured by the amount of heat liberated when feed substances are burned, proteins and carbohydrates yield approximately 4 kcal per g and fat yields approximately 9 kcal per g. Thus, fat has 2.25 times the energy value of protein or carbohydrates. (Although these figures are frequently cited as the physiological fuel value of protein, carbohydrates, and fats, much variation occurs depending on the particular feedstuff.) Although protein supplies as much energy as carbohydrates, protein is not normally used as an energy source because energy can be supplied more economically through either carbohydrates or fats.

Energy in feeds may be measured in various ways depending on the particular interest of the individual desiring the information. It is important, however, that one understand the biological meaning of the information that is obtained by the different methods. The functions of various forms of energy in the body are outlined in Table 11-1.

"TDN" means "total digestible nutrients." If one expresses TDN as a percentage (% TDN), it is the sum of the percentages of digestible protein, crude fiber, nitrogen-free extract, and ether extract (fat or lipid) x 2.25. It is one method of evaluating the energy value of a feed because much of the loss of the total energy in a feed occurs through digestion.

**Table 11-1. The utilization of energy.**

- Food Intake (Gross energy)
  - 1. Apparent digestible energy
    - 1. Metabolizable energy
      - 1. Net energy
        - 1. Production energy
          - A. Energy storage
            - a. Storage of energy in fetus and in body of pregnant female
            - b. Semen in male
            - c. Growth
            - d. Milk
            - e. Eggs
            - f. Fur
            - g. Wool
          - B. Work
        - 2. Maintenance energy
          - *A. Basal metabolism
          - *B. Voluntary activity
          - *C. Heat to keep body warm
          - *D. Energy to keep body cool
      - 2. Heat increment
        - *A. Heat of fermentation
        - *B. Heat of nutrient metabolism
    - 2. Gaseous products of digestion
    - 3. Urinary energy
      - A. Food origin
      - B. Body origin
  - 2. Fecal energy
    - A. Food origin
    - B. Metabolic origin

*Expended as heat.

One gram of TDN is roughly equivalent to 4 kcal of energy. TDN is an overall estimate of the energy in a feed.

Several factors may influence digestibility:

1. *"Balance" of the ration.* ("Balance" here refers to the amount of protein in relation to the amount of other nutrients in the feed.) Rations that are quite low in protein may be very low in digestibility.
2. *Combinations of feed ingredients.* Fiber in the ration tends to reduce digestibility of the concentrates.
3. *Rapidity of movement of substances through the digestive tract.* Magnesium sulphate, which is often found in alkaline water, or large amounts of molasses or lush pasture that are often provided for cattle cause feed to pass through the digestive tract so rapidly that digestion and absorption are reduced.
4. *High-energy sources in feed.* High-energy sources reduce fiber digestibility. When ruminants are given high-energy feeds along with roughages, the microorganisms obtain their nutrients from the high-energy feeds instead of breaking down the roughages.
5. *Feed intake.* When large amounts of feed are consumed, digestibility is reduced.
6. *Preparation of feed.* Grinding, cracking, or rolling of grains provides an opportunity for the enzymes of the digestive tract to act upon the feed and prevents grains of such feeds as barley and wheat from passing through the animal as whole kernels. Hay that is finely cut may approach some concentrates in level of digestibility.

The amount of gross energy in a feed may be measured by combusting the feed and measuring the amount of heat that it liberates. This method of measuring energy may be of little value because it does not provide information on how much usable energy the animal could obtain from the feed. Sawdust, for example, contains a large amount of combustible, or gross, energy, but it provides little or no energy to a farm animal because it is highly indigestible.

Digestibility of energy is determined by measuring the kcal of energy ingested and the kcal voided through the feces. The kcal in the feed and feces is determined by measuring the heat produced when these materials are combusted. The digestibility of energy is calculated as follows:

$$\text{Digestibility of energy} = \frac{\text{kcal ingested - kcal in feces}}{\text{kcal ingested}} \times 100$$

Digestible energy is expressed in kcal per kilogram (kg) of feed. It is calculated by multiplying the total kcal in 1 kg of feed by the digestibility of the energy. This method of expressing digestible energy provides information on how much energy of the feed is digested, but it does not provide information on how much energy is available to the animal for body processes. Metabolizable energy is the digestible energy minus energy lost when energy-containing substances are passed in urine and when combustible gases are lost in eruction (belching) or in defecation. Energy losses through combustible gases may be sizable in ruminants because ruminants eruct considerable quantities of methane.

Net energy is the energy available for use by the animal. It is the metabolizable energy minus the loss from heat increment. Heat increment is the amount of heat lost as a result of the physical and chemical processes which are associated with metabolism. Its components are the heat of nutrient metabolism and that of fermentation. Net energy is available to the animal for such body processes as maintenance, growth, reproduction, lactation, and work.

Energy expenditure may be measured by respiratory studies in which one determines the amount of oxygen ($O_2$) consumed and the amount of carbon dioxide ($CO_2$) released. Energy expenditure is a measure of the metabolism that is occurring in an animal's body. Basal metabolism is the metabolism that is measured when the animal is quiet and is not digesting food; consequently, it is a measure of metabolism that avoids the complications that are introduced when one must measure the energy expended for digestion and muscular activity. Basal metabolism can be determined for monogastric animals, such as pigs and humans, but not for ruminants. It is highly unlikely that a ruminant does not ever have feed passing from the rumen to the abomasum. Some feed is still present in the rumen even in cattle that have died of starvation.

The slaughter technique is sometimes used for determining the use that is made of energy consumed by growing animals. Three groups of similar animals are used. Animals of one group are slaughtered and their bodies are analyzed to obtain a measure of how much energy is present in the bodies of the members of all three groups. The amount of energy in the bodies of animals can be determined through combustion or through an analysis of the amounts of protein, fat, and ash, after which the energy can be calculated. The amount of carbohydrate in the animal body is generally low, but it should also be determined for a precise assessment. The second group is allowed only enough feed for each individual to maintain its body weight, so that the amount of energy required for body maintenance can be estimated. The third group is fed *ad libitum* (that is, given free access to all the feed desired). Its members are finally slaughtered and their bodies are analyzed in the same way as the members of Group 1. Through the slaughter technique, one can calculate the energy required for gain. The quantity of energy initially present in the bodies of animals in Group 1 subtracted from the quantity of energy in the bodies of animals in Group 3 at the time of slaughter gives the energy stored. Energy consumed by Group 3 (fed *ad libitum*) minus the energy consumed by Group 2 (maintenance) gives an estimate of how much energy was used by the Group 3 animals to achieve an increase in weight.

**Minerals.** Some minerals are needed in relatively large amounts by animals, whereas other minerals are required in small amounts. Those needed in large amounts are called macrominerals; those needed in small amounts are called microminerals. (Note that the terms macromineral and micromineral do not refer to molecular size of the minerals.) Microminerals have also been called "trace" minerals because only a trace, or minute quantity, is needed.

The macrominerals include calcium, phosphorus, sodium, potassium, chlorine, sulphur, and magnesium. Calcium and phosphorus are required in certain amounts and in a certain ratio to each other for bone growth and repair and for other body functions. The blood plasma

contains sodium chloride; the red blood cells contain potassium chloride. The osmotic relations between the plasma and the red blood cells are maintained by proper concentrations of sodium chloride and potassium chloride. Sodium chloride may be depleted by excessive sweating when heavy physical work is done in hot weather. It is essential that salt and plenty of water be available under such conditions. This is the reason people are advised to take salt pills when they work hard in hot weather. The acid-base balance of the body is maintained at the proper level by minerals.

The microminerals include iodine, zinc, manganese, cobalt, copper, iron, molybdenum, selenium, and fluorine. Minerals may activate or act as cofactors for enzyme action or vitamin use (for example, cobalt is needed as a part of vitamin $B_{12}$). Thyroxine, a hormone made by the thyroid gland, requires iodine for its synthesis.

Hemoglobin of the red blood cells carries oxygen to tissues and carbon dioxide from tissues. Iron is required for the production of hemoglobin because it is a part of the hemoglobin molecule. A small quantity of copper is necessary for the production of hemoglobin (even though it does not normally become a part of the hemoglobin molecule in farm animals) because it apparently is necessary for normal iron absorption from the digestive tract and for release of iron to the blood plasma.

Certain important metabolic reactions in the body require the presence of minerals. Selenium and vitamin E both appear to work together to help prevent white muscle disease, which is a calcification of the striated muscles, the smooth muscles, or both. Both vitamin E and selenium are more effective if the other is present. Excesses of certain minerals may be quite harmful. Excess amounts of fluorine, molybdenum, and selenium are highly toxic.

**Vitamins.** Vitamins may be classed as either fat-soluble or water-soluble. The fat-soluble vitamins are vitamins A, D, E, and K. Vitamin A helps maintain proper repair of internal and external body linings. Because the eyes have linings, lack of vitamin A adversely affects the eyes. Vitamin A is also a part of the visual pigments of the eyes. Vitamin D is required for proper use of calcium and phosphorus in bone growth and repair. Vitamin D is produced by the action of sunlight on steroids of the skin; therefore, animals that are exposed to sufficient sunlight make all the vitamin D that they need. Vitamin K is important in blood clotting; hemorrhage may occur if the body is deficient in vitamin K. Aspirin, which is sometimes given to pet horses, dogs, and cats that are old and arthritic, may react with vitamin K to prevent its function; therefore, the taking of large amounts of aspirin may cause the body to require more vitamin K than normal. Vitamin E was once thought to be important in reproduction in animals because laboratory rats have failed to reproduce when fed a ration deficient in vitamin E. Vitamin E has not been shown to be important in reproduction in farm animals, but it does prevent white muscle disease in cattle and sheep.

The water-soluble vitamins are thiamine (vitamin $B_1$), riboflavin (vitamin $B_2$), niacin, pyridoxine (vitamin $B_6$), pantothenic acid, biotin, folic acid, cyanocobalamine (vitamin $B_{12}$), ascorbic acid (vitamin C), inositol, choline, and para-aminobenzoic acid. More deficiency diseases have been described in the human than in any other animal. Some that

are caused by a lack of certain vitamins are: beri-beri (lack of thiamine); pellegra (lack of niacin); pernicious anemia (lack of vitamin $B_{12}$); rickets (lack of vitamin D); and scurvy (lack of vitamin C).

In ruminant animals, most of the water-soluble vitamins are either made by microorganisms in the rumen or are not needed. Water-soluble vitamins also appear to be readily available to horses; perhaps some are made by fermentation in the cecum. The water-soluble vitamins cannot be synthesized by monogastric animals and must therefore be in their feed. The fat-soluble vitamins are not synthesized by either the ruminants or the monogastrics; consequently, they must be supplied in the ration of both groups. Many vitamins are supplied through normal feeds that are given animals.

Other feeds occasionally react with certain vitamins in such a way as to prevent those vitamins from being available to the animal. For example, bracken fern contains tyrosinase, which, when eaten by cattle and horses, splits vitamin $B_1$ (thiamine) into simpler constituents that lack vitamin activity. (Bracken fern is not normally eaten, but when grasses and forbs are in extremely short supply, succulent fern growth may be eaten.)

## Study Questions and Suggestions

1. a. Upon what basis are feeds categorized as concentrates or roughages?
   b. Classify the following feeds as concentrates or roughages: clover hay, corn, tankage, straw, soybean meal, silage, molasses, and corn stover.
2. a. What is meant by "essential" amino acids?
   b. Do ruminant animals need to be fed "essential" amino acids?
   c. How is the protein content of a feed determined? Is it possible that the chemical determination of protein content of a feed may not indicate the actual protein content of the feed? Would an erroneous estimate of the amount of protein present in a feed be more important in feeding monogastric animals or ruminants?
   d. What are the functions of carbohydrates and fats?
3. List five factors that may influence digestibility of a ration.
4. Differentiate the following: gross energy, digestible energy, net energy, and metabolizable energy.
5. What is meant by macrominerals and microminerals? List five minerals that are classed as macrominerals and five that are classed as microminerals.
6. a. List three fat-soluble and three water-soluble vitamins. Indicate how each is important.
   b. What vitamins that can be made by ruminants must be supplied to monogastric animals?

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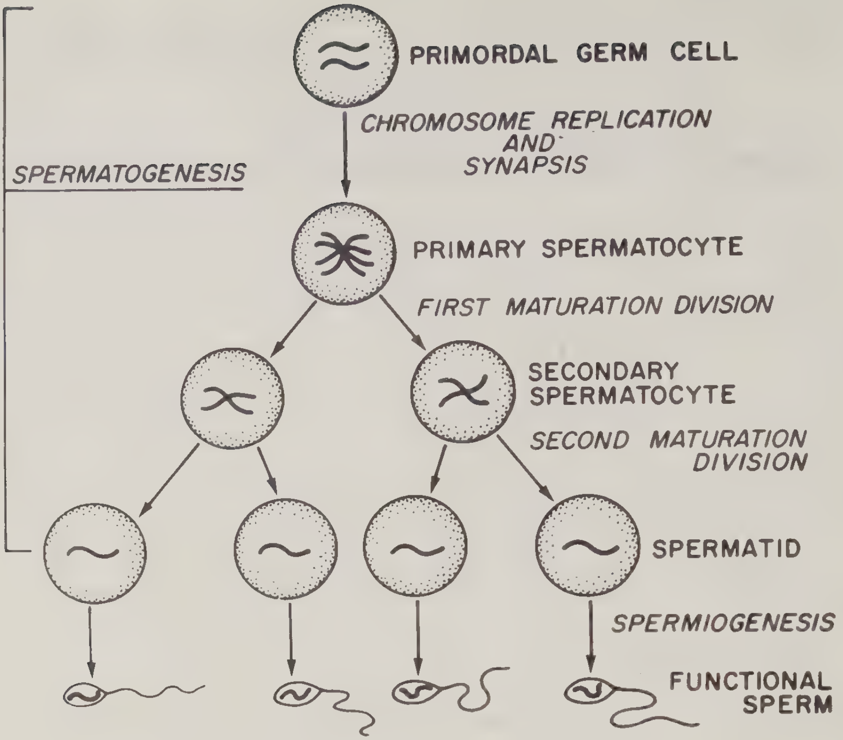
# 13. Genetics—The Study of Inheritance

If one examines certain body tissues microscopically, it will be observed that the tissues are composed of cells. The cells, with certain exceptions, have an outer membrane inside of which is the cytoplasm (cell sap). Within the cytoplasm is a body called the nucleus. The nucleus contains rodlike bodies called chromosomes. *Chromosome* means "colored body." Chromosomes are so named because they are bodies that stain readily with chrome dyes. When the body cells divide to produce other body cells, the chromosomes line up along an equatorial plate, duplicate themselves, and later separate in such a way that each of the two cells produced (daughter cells) contains the same chromosome composition as was present in the original (mother) cell. The division of body cells to form daughter cells that contain the same chromosome composition as the mother cells is called *mitosis.*

## The Production of Gametes

The testicles of the male and the ovaries of the female produce cells that become gametes (sex cells) by a process called *gametogenesis.* The gametes produced by the testicles are called sperm; the gametes produced by the ovaries are called eggs, or ova. Specifically, the production of sex cells that will become sperm is called spermatogenesis; the production of ova, oogenesis. Fundamental to gametogenesis is *meiosis,* a special type of nuclear division in which the germ cells, each of which contains one member of each of the pairs of chromosomes present in the body cells, are formed.

FIGURE 13-1. *Spermatogenesis and spermiogenesis in which one pair of chromosomes is illustrated. Note that four sperm result from one primordal germ cell.*




The chromosomes are normally in pairs in an individual. Let us examine gametogenesis in a theoretical species whose members have one pair of chromosomes in each cell. In the primordial germ cells located near the outer wall of the seminiferous tubules of each testicle and near the surface of each ovary, two things happen—the chromosomes replicate (duplicate) themselves and they synapse (come together). The cell after replication and synapsis is called a primary spermatocyte in the male and a primary oocyte in the female. Because subsequent differences exist between spermatogenesis and oogenesis, the two will be described separately.

**Spermatogenesis.** The process of spermatogenesis in our theoretical species is shown in Figure 13-1. The primary spermatocyte contains a body of four parts formed by its pair of replicated chromosomes. This body is called a tetrad ("tetra-" means "four"; "-ad" means "body"). By two rapid divisions that involve no further replication of the chromosomes, four cells, each of which contains one chromosome, are produced. The first of these two divisions is called the first maturation division. From it are produced two secondary spermatocytes, each of which contains a chromosomal body of two parts, called a dyad ("di-" means "two"; "-ad" means "body"). The second maturation division, in which each of the two secondary spermatocytes divides, results in the production of four spermatids, each of which contains one chromosome.

By a process called spermiogenesis, which is not a part of spermatogenesis, the spermatids each lose much of their cytoplasm and develop a tail. As a result of spermiogenesis, mature male sex cells (spermatozoa, or sperm) are produced. Four sperm are produced from each primary spermatocyte. Whereas a *pair* of chromosomes is present in the primordial germ cell, only *one* chromosome is present in each

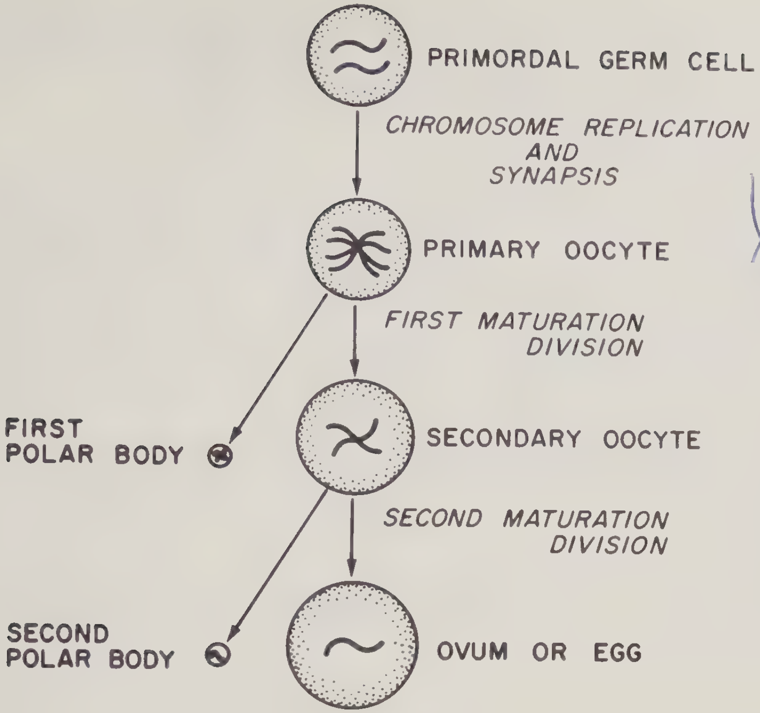



FIGURE 13-2. *Oogenesis in which one pair of chromosomes is illustrated. Note that only one egg results from a primordal germ cell and that it contains considerable amounts of nutrients.*

sperm. Thus, the number of chromosomes in the sperm has been reduced to half the number in the primordial germ cell.

**Oogenesis.** The process of oogenesis in our theoretical species is shown in Figure 13-2. Like the primary spermatocyte of the male, the primary oocyte of the female contains a tetrad. The first maturation division produces one relatively large, nutrient-containing cell, the secondary oocyte, and a smaller cell, the first polar body. Each of these two cells contains a dyad. The unequal distribution of nutrients that results from the first maturation division in the female serves to maximize the quantity of nutrients in one of the cells (the secondary oocyte) at the expense of the other (the first polar body). The second maturation division produces one egg, or ovum, and the second polar body, each of which contains one chromosome. The first polar body may also divide, but all polar bodies soon die and are reabsorbed. Note that the egg, like the sperm, contains only one chromosome of the pair that was present in the primordial germ cell. The gametes each contain one member of the pair of chromosomes that existed in each primordial germ cell.

## Fertilization

When a sperm and an egg of our theoretical species unite to start a new life, each contributes one chromosome to the pair of chromosomes of the fertilized egg, now called a zygote. Fertilization is defined as the union of the sperm and the egg along with the establishment of the paired condition of the chromosomes. The zygote is termed *diploid* because it has chromosomes in pairs, one member of each pair having come from the sire and one member having come from the dam. Gametes have only one member of each pair of chromosomes; therefore,

gametes are termed *haploid* ("haplo-" means "half"). Gametogenesis thus reduces the number of chromosomes in a cell to half the diploid number. Fertilization reestablishes the diploid state.

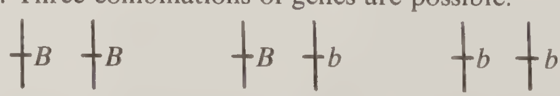
## Genes and Chromosomes

It has been mentioned that chromosomes occur in pairs in diploid cells. The two members of a typical pair of chromosomes synapse with each other in meiosis, are alike in size and shape, and carry *genes* that affect the same hereditary characters. Such chromosomes are said to be *homologous.* The genes are points of activity found in each of the chromosomes that govern the way in which physical traits develop. The genes form the coding system that directs enzyme and protein production. They thus control the development of traits.

Because the chromosomes are in pairs, the genes are also in pairs. The location of a gene in a chromosome is called a *locus* (plural, loci). For each locus in one of the members of a pair of homologous chromosomes, there is a corresponding locus in the other member of that chromosome pair. The transmission of genes from parents to offspring depends entirely upon the transmission of chromosomes from parents to offspring. Where there is a pair of chromosomes, there is one gene in each at each locus. (A special pair of chromosomes, the so-called "sex chromosomes," may exist as a pair in which one of the chromosomes does not correspond entirely to the other in terms of what gene loci are present. For a discussion of sex chromosomes, the reader should consult an introductory genetics text.)

The genes located at corresponding loci in homologous chromosomes may correspond to each other in the way that they affect a trait, or they may contrast. If the genes correspond in the way that they affect a trait, the individual is said to be *homozygous* at that locus ("homo-" means "alike"; "-zygous" refers to the individual). If the genes are different in the way that they affect a trait, the individual is said to be *heterozygous* ("hetero-" means "different"; "-zygous" refers to the individual). Those genes that occupy corresponding loci in homologous chromosomes but affect the same character in different ways are called *alleles.*

The geneticist usually illustrates the chromosomes as lines and indicates the genes by alphabetical letters. When the genes at corresponding loci on homologous chromosomes are unlike, one of the genes often overpowers, or dominates, the expression of the other. This gene, or allele, is called *dominant.* The gene whose expression is prevented is called *recessive.* The dominant gene is symbolized by a capital letter. The recessive gene is symbolized by a lower case letter. For example, in cattle, black hair color is dominant to red hair color, so we let $B$ = black and $b$ = red. Three combinations of genes are possible:




Both *BB* animals and *bb* animals are homozygous for the genes that determine hair color, but one is homozygous dominant (*BB*) and the other is homozygous recessive (*bb*). The animal that is *Bb* is heterozygous; it has allelic genes.

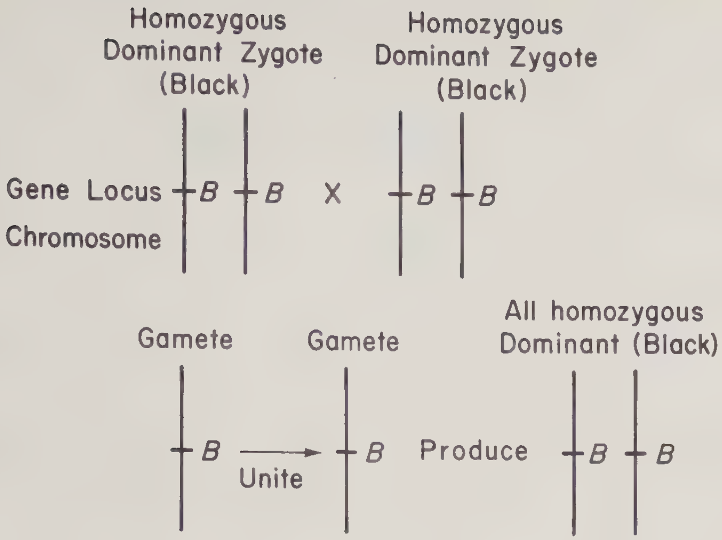



FIGURE 13-3. *Mating of homozygous dominant x homozygous dominant.*

## The Six Fundamental Types of Mating

With three kinds of individuals (homozygous dominant, heterozygous, and homozygous recessive) and one pair of genes involved, six types of matings are possible. Using the genes designated as *B* = black and *b* = red in cattle, the six mating possibilities are: *BB* x *BB; BB* x *Bb; BB* x *bb; Bb* x *Bb; Bb* x *bb;* and *bb* x *bb.* Keep in mind that the discussion based on these genes is applicable to any other pair of genes in any species.

**Homozygous dominant x homozygous dominant (*BB* x *BB*).** When two homozygous dominant individuals are mated, each of them can produce only one kind of gamete, namely, the gamete carrying the dominant gene. In the particular example that we are using, this gamete carries gene *B*. The union of gametes from two homozygous dominant parents results in a zygote that is homozygous dominant (*B* x *B* = *BB*). Thus, homozygous dominant parents produce only homozygous dominant offspring (Figure 13-3).

**Homozygous dominant x heterozygous (*BB* x *Bb*).** The mating of a homozygous dominant with a heterozygous individual results in an expected ratio of 1 homozygous dominant: 1 heterozygous. The homozygous dominant parent produces only one kind of gamete, the one carrying the dominant gene (*B*). The heterozygous parent produces two kinds of gametes, one carrying the dominant gene (*B*) and one carrying the recessive gene (*b*). The latter two kinds of gametes are produced in approximately equal numbers. The chances that a gamete from the parent producing only the one kind of gamete (the one having the dominant gene) will unite with each of the two kinds of gametes produced by the heterozygous parent are equal; therefore, the number of homozygous dominant offspring (*B* x *B* = *BB*) and heterozygous offspring (*B* x *b* = *Bb*) produced should be approximately equal (Figure 13-4).

**Homozygous dominant x homozygous recessive (*BB* x *bb*).** The homozygous dominant individual can produce only gametes carrying

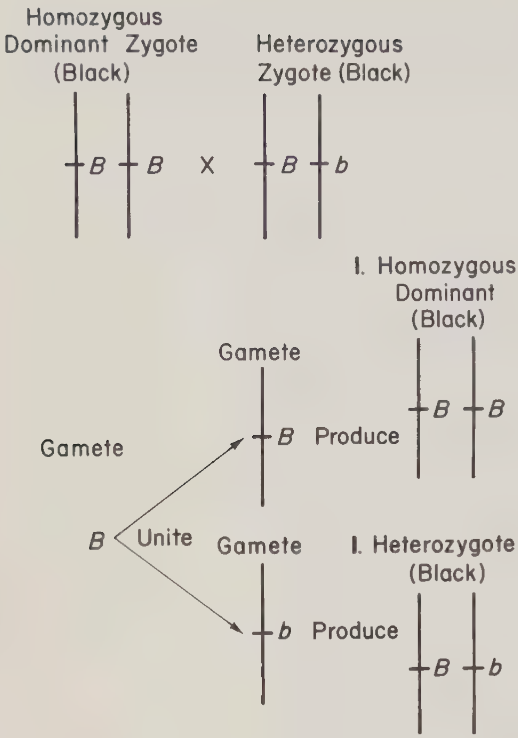
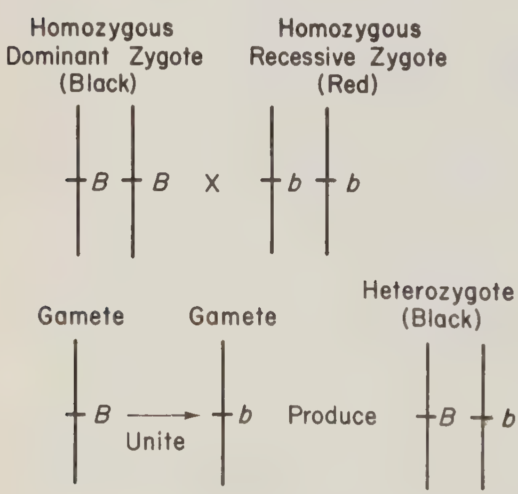



FIGURE 13-4. *Mating of homozygous dominant x heterozygote.*

FIGURE 13-5. *Mating of homozygous dominant x homozygous recessive.*



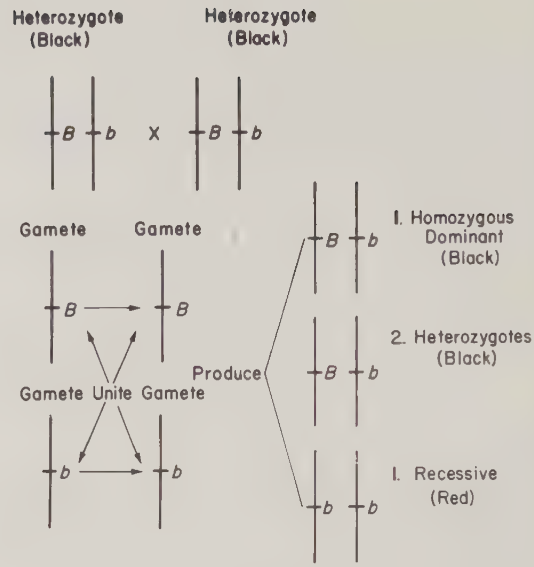
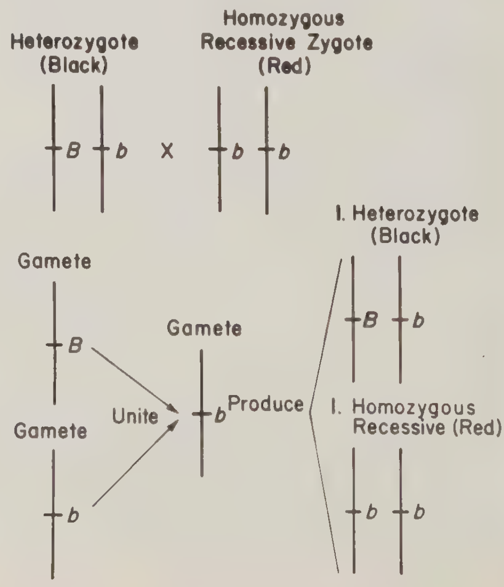




FIGURE 13-6. *Mating of heterozygote x heterozygote.*

FIGURE 13-7. *Mating of heterozygote x homozygous recessive.*



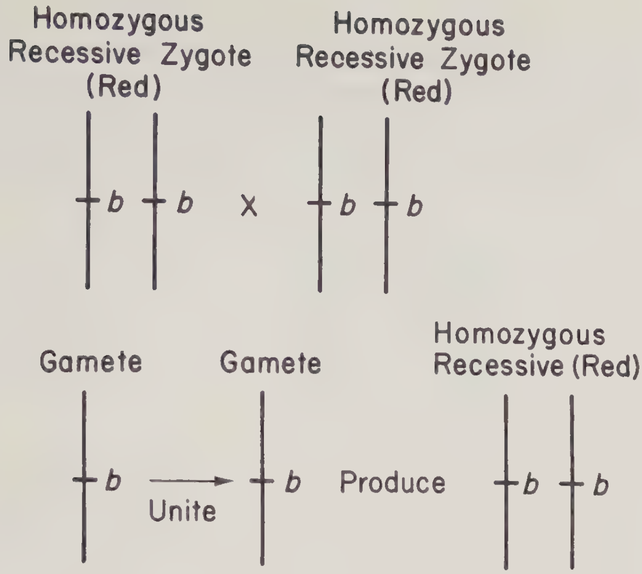



FIGURE 13-8. *Mating of homozygous recessive x homozygous recessive.*

the dominant gene ($B$). The recessive individual must be homozygous recessive in order to show the recessive trait; therefore it produces only gametes carrying the recessive gene ($b$). When the two kinds of gametes unite, all offspring produced receive both the dominant and the recessive gene ($B$ x $b = Bb$) and are thus all heterozygous (Figure 13-5).

**Heterozygous x heterozygous (*Bb* x *Bb*).** Each of the two heterozygous parents produces two kinds of gametes in approximately equal ratios: one kind of gamete carries the dominant gene ($B$); the other kind carries the recessive gene ($b$). The two kinds of gametes produced by one parent each have an equal chance of uniting with each of the two kinds of gametes produced by the other parent. Thus, four equal-chance unions of gametes are possible. If the gamete carrying the $B$ gene from one parent unites with the gamete carrying the $B$ gene from the other parent, the offspring produced are homozygous dominant ($B$ x $B = BB$). If the gamete carrying the $B$ gene from one parent unites with the gamete carrying the $b$ gene from the other parent, the offspring are heterozygous ($B$ x $b = Bb$). There are two ways in which the latter combination of genes can occur: the $B$ gene can come from the male parent and the $b$ gene from the female parent, or the $B$ gene can come from the female parent and the $b$ gene from the male parent. When the gametes carrying the $b$ gene from both parents unite, the offspring produced are recessive ($b$ x $b = bb$).

The total expected ratio among the offspring of two heterozygous parents is 1 $BB$: 2 $Bb$: 1 $bb$ (Figure 13-6). This ratio is the genetic, or *genotypic,* ratio. The appearance of the offspring is in the ratio of 3 dominant: 1 recessive because the $BB$ and $Bb$ animals are all black (dominant), and cannot be genetically distinguished from one another by looking at them. This ratio, based on external appearance, is called the *phenotypic* ratio.

**Heterozygous x homozygous recessive (*Bb* x *bb*).** The heterozygous individual produces two kinds of gametes, one carrying the dominant gene ($B$) and the other carrying the recessive gene ($b$), in approximately

equal numbers. The recessive individual produces only the gametes carrying the recessive gene ($b$). There is an equal chance that the two kinds of gametes produced by the heterozygous parent will unite with the one kind of gamete produced by the recessive parent ($B \times b = Bb$; $b \times b = bb$). The offspring produced when these gametes unite thus occur in the expected ratio of 1 heterozygous: 1 homozygous recessive (Figure 13-7).

**Homozygous recessive x homozygous recessive ($bb \times bb$).** The recessive individuals are homozygous; therefore, they can produce gametes carrying only the recessive gene ($b$). When these gametes unite ($b \times b = bb$), all offspring produced will be recessive (Figure 13-8). This example illustrates the principle that recessives, when mated together, breed true.

The knowledge of what results from each of the six fundamental types of matings provides a background for understanding complex crosses. When more than one pair of genes are involved in a mating, one can understand the expected results because one can combine each of the combinations of one pair of genes with each of the other combinations of one pair of genes to obtain the expected ratios.

## Parental and Filial Generations

In genetics research the dominant is often mated with the recessive, after which the offspring are intermated. If we use the same genes as before ($B$ = black and $b$ = red), the mating sequence is:

| | |
|---|---|
| First parental ($P_1$) generation | |
| (or $P_1$ zygotes) | ***BB*** x ***bb*** |
| $P_1$ gametes | ***B*** ***b*** |
| First filial ($F_1$) generation | |
| (or $F_1$ zygotes) | ***Bb*** |
| $F_1$ zygotes | ***Bb*** x ***Bb*** |
| $F_1$ gametes | ***B, b B, b*** |
| $F_2$ zygotes | ***BB, Bb, Bb, bb*** |

## More Than One Pair of Genes

Suppose that there are two pairs of genes, each pair affecting a particular trait, to be considered. Let us consider two pairs of genes, one pair of which determines coat color in cattle, and the second pair of which determines whether the animal is hornless (polled) or horned. The genes are designated as follows: $B$ = black, $b$ = red, $P$ = polled, and $p$ = horned. If a bull that is heterozygous for both traits ($BbPp$) is mated to cows that are also heterozygous for both traits ($BbPp$), one can determine the expected phenotypic and genotypic ratios.

$BbPp \times BbPp$ produces the following phenotypes: 3 to 1

$$\text{3 black (dominant)} \begin{cases} \text{3 polled} = \text{9 black polled} \\ \text{1 horned} = \text{3 black horned} \end{cases}$$

$$\text{1 red (recessive)} \begin{cases} \text{3 polled} = \text{3 red polled} \\ \text{1 horned} = \text{1 red horned} \end{cases}$$

The three of the black x the three of the polled gives nine black polled and the three of the black x the one of the horned gives three black horned. Likewise, the one of the red x the three of the polled gives three red polled and the one of the red x the one of the horned gives one red horned.

The genotypic ratio expected when *BbPp* x *BbPp* matings are made is:

1-2-1

| | | | |
|---|---|---|---|
| 1 *BB* | 1 *PP* | = | 1 ***BBPP*** |
| | 2 *Pp* | = | 2 ***BBPp*** |
| | 1 *pp* | = | 1 ***BBPp*** |
| 2 *Bb* | 1 *PP* | = | 2 ***BbPP*** |
| | 2 *Pp* | = | 4 ***BbPp*** |
| | 1 *pp* | = | 2 ***Bbpp*** |
| 1 *bb* | 1 *PP* | = | 1 ***bbPP*** |
| | 2 *Pp* | = | 2 ***bbPp*** |
| | 1 *pp* | = | 1 ***bbpp*** |

## Study Questions and Suggestions

1. Diagram spermatogenesis and spermiogenesis using one pair of chromosomes and label the following: primary spermatocyte, secondary spermatocyte, spermatid, sperm, first maturation division, and second maturation division.
2. How does oogenesis differ from spermatogenesis?
3. In cattle $B$ = black and $b$ = red. A heterozygous (*Bb*) bull is mated to a herd of heterozygous (*Bb*) cows. What genotypic ratio would you expect among the offspring? What phenotypic ratio would you expect?
4. In cattle, $B$ = black, $b$ = red, $P$ = polled, and $p$ = horned. A black, polled bull is bred to a black, polled cow and produces a red, horned calf. What is the genotype of the bull, the cow, and the calf?
5. You should learn the six fundamental types of matings that can be made when one pair of genes is involved.

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# 15. Tools in Selection

The person who is breeding farm animals has the following tools, or aids, that can be used in selection: appearance, pedigree, production records, progeny tests, and family records. Each of these tools has a place and each has certain strengths and weaknesses. To assist in using these tools, they will be evaluated to show where they have value and where they might be of no value.

## Appearance

Any animal that is being considered for selection is present at some location and is available to be seen. The appearance of an animal is important in (1) telling one whether or not the animal has any inherited anatomical abnormalities, and in (2) providing an estimate of the merit of the carcass that could be made from the animal. Any animal that has such inherited abnormalities as crooked legs, undershot or overshot jaws, cryptorchidism (one testicle retained in the abdomen), or hernia (rupture in either the navel region or the scrotal region) should not be kept for breeding. Environmentally caused abnormalities (such as loss of tail and bad wire cuts) that do not interfere with the animal's breeding should not cause one to cull the animal.

One cannot determine with complete accuracy the type of carcass an animal will make, but certain considerations can increase the accuracy of the estimate. One of the most important characteristics of a beef carcass is its *lean cutability.* If one observes the areas of the body where little external fat is deposited (the sides of the round) and the areas where

large amounts of external fat are stored (over the shoulders, on the briskets, and in the rear flank region), fairly accurate estimates of lean cutability can be made. An animal that is bulging at the sides of the round, clean-cut over the shoulders and at the brisket, and that shows a small amount of cod (udder fat) will have a high lean cutability.

One thing that must be kept in mind in using appearance of animals to estimate carcass merit is that the estimation should be done at the stage of life in which animals are normally made into carcasses. A young, nursing animal or an old, producing animal cannot be accurately appraised for carcass merit. In fact, the use of visual appraisals of very young or of mature animals may result in costly mistakes. Producing females that are doing well in raising their young are likely to present an unpleasant appearance, whereas females that are giving little milk for their young may appear highly desirable. Young animals differ from adults in that they have relatively long legs and necks and appear ungainly. However, they are at a gangling, awkward stage of life and should not be criticized for lack of a smooth appearance. When one views a young animal but has in mind the image of a larger animal, only the smooth, plump young seem appealing; these individuals, however, are likely to grow less rapidly than the others.

## Pedigree

A pedigree is a record of the ancestry of an animal. Unless production records of the ancestors of the animal are included with the pedigree, the pedigree tells very little about the genetic merit of the animal. When no records concerning the ancestors of an animal are available, the pedigree provides information only on the relationship of its parents, from which its extent of inbreeding can be determined. If two animals are of equal merit and one is inbred whereas the other is not, the inbred animal is more likely to transmit its phenotype than the other.

Some people emphasize the occurrence in a pedigree of an ancestor that has placed high in livestock shows. The occurrence of such an ancestor in a pedigree may or may not be an indication of an animal's genetic value for show standards. Some great show animals are produced by fortunate "nicking" in the mating that was made (meaning that the mating resulted in an outstanding offspring). Such show animals are not likely to transmit their desirable conformation to their offspring.

When production records concerning the ancestors are available, the pedigree becomes more valuable. However, certain considerations must be given if accurate evaluations based on such a pedigree are to be made. Some pedigrees have records of some of the ancestors but not of all of them. Unless one knows why some records are missing, the logical conclusion is that the performance of certain animals was so poor that no records were entered. One should keep in mind also that outstanding records on only a few ancestors that lived six or eight generations ago are not a good indication that the animal in question will inherit outstanding traits from those ancestors. However, if an individual ancestor has a high record and this individual occurs several times in the pedigree, the chances are good that the animal in question has inherited

some genetic material from the outstanding individual. In general, one should give most attention to records of parents and grandparents. Another important consideration is that low records are as likely to be transmitted to the animal under consideration as are high records.

The value of records in a pedigree depends upon the accuracy with which they were recorded and upon the integrity of the person who kept the records. Most breeders of purebred stock are highly honest. Some honest mistakes will be made, but not many. Unfortunately, there are a few people in the purebred business who think of the pedigree only as a marketing gimmick, and they make the pedigree as appealing as possible. This type of person is usually not in the purebred business for very long because such a method of keeping records is soon revealed and the resulting low reputation that such a person acquires makes it difficult for that person to market animals. The pedigree is most useful in selection when the traits considered are low to moderate in their degree of heritability.

## Production Records

Production records are useful for selection when traits are moderate to high in their degree of heritability, but little progress will be made from selection based on production records of traits that are low in their degree of heritability. Production records can be influenced to make them appear better than they actually are. For example, if a calf is weaned and put on a roughage ration for a period of 2 to 3 months, it will make a rather high rate of gain and will be quite efficient in feed conversion when it is placed on a feed-testing program because it is compensating for the austerity it previously experienced. One should give attention to weight-per-day of age (the weight that an animal has for each day that it has lived: weight-per-day of age $= \frac{\text{weight}}{\text{age}}$) as well as to rate of gain during the feed-testing program. Even though an animal has a good rate of gain during the feed-testing program, it is not highly desirable if its weight-per-day of age is low. The accuracy with which records are established and the honesty of those who obtain records are important considerations.

## Progeny Testing

The evaluation of an animal on the basis of its own record is called *performance testing*. The evaluation of an animal on the basis of the performance of its offspring is called *progeny testing*. One should clearly differentiate between these two methods of evaluation.

Progeny testing is most useful in a species in which the trait being tested is expressed in only one sex, such as milk production by dairy cows and goats or egg production by poultry. Progeny testing is also useful in evaluating carcass merit. It is the most accurate method of evaluating an animal's breeding value. One must keep in mind that even though progeny testing is highly accurate, it may not be the most useful method. When traits are highly heritable, one can make more progress from selection on the individual's record than by progeny testing because of the long time required for progeny testing.

To progeny test, one must grow the animal to breeding age and size, breed it to several animals, wait for them to have young, and obtain records on the young. This usually means that one could produce two generations by selecting an individual on the basis of its own record in the same time that one could produce one generation through progeny testing.

Progeny testing also requires the production of several offspring to accurately evaluate the breeding value of an individual. One also needs to progeny test several animals in order to assure finding one that is good. These requirements mean that progeny testing may be expensive, requiring a large outlay if it is to be done properly. Quite often, purebred breeders contract with commercial producers as a means of doing progeny testing.

Progeny testing to evaluate the breeding value of an animal for carcass merit does not require as many offspring for accuracy as is required to evaluate milk-producing ability. Eight steers by each sire should provide sufficient information for evaluating a bull's breeding value for carcass merit, whereas 40 to 50 offspring are needed to properly evaluate a bull's transmitting ability for milk production.

With most farm animals, progeny testing can be done on only the males because female cattle, horses, and sheep do not produce enough offspring in order to be progeny tested and still be available later for breeding in the herd. Poultry and possibly swine females could be progeny tested.

Another use of progeny testing is detection of undesirable recessive genes present in herds and flocks. It may be important to know that the male that one is using for breeding is free from undesirable traits caused by recessive genes. If the undesirable trait does not impair reproduction or cause death, one can use undesirable females for breeding to males that are to be tested. Only eight offspring, all not showing the undesirable trait, are needed to give reasonable assurance that the male being tested does not carry a particular undesirable gene. Keep in mind that one never proves that a male does not carry an undesirable gene. Even if the odds against a particular gene being present are 999:1, it does not absolutely prove that an animal is free from the gene. When an undesirable recessive gene impairs fertility or causes death, one cannot use the undesirable recessive animal for breeding. The most appropriate method to test for any and all undesirable genes is to mate the animal being tested to several of his daughters. To obtain reasonable assurance that the male carries no undesirable genes, 30 to 35 offspring resulting from mating a sire to his daughters are required.

A program was developed by Armour Food Co. whereby young beef bulls with outstanding performance records were obtained and bred by artificial insemination to about 80 cows each. The male calves that resulted were castrated and put into a feedlot after weaning. When they reached slaughter weights of approximately 1,000 lbs., they were slaughtered and their carcasses were evaluated. The female calves were grown to sexual maturity and bred to their sire. When these females calved, milk production was evaluated for each one on the basis of how much weight their calves gained (suckling gain) in the period when they were nursed by their mothers. Careful observations were made of all calves born to determine if any had an inherited abnormality. This pro-

gram provided information on each bull's rate and efficiency of gain, the carcass merit of his steer offspring, the ability of his daughters to produce milk for their young, and whether or not the bull carried any undesirable genes. Bulls of merit under this type of testing program could be used widely through a commercial artificial insemination program to provide marked improvement in beef cattle production.

## Family Selection

Relatives other than ancestors or offspring indicate to a limited extent what level of performance one might expect from an animal. Thus, a young male coming from a herd, a line, or a strain in which all animals have good performance records is more likely to have good performance than an animal that comes from a herd in which many of the animals are mediocre or inferior.

In some herds, one can see that a previous mating program has resulted in smaller families. Observations on performance in each of the families may reveal that performance is high in most or all animals of some families but that other families may contain several animals that show performance which is quite low. An effective way to improve such a herd is to cull all families having low performance and keep replacements only from families having good performance. Of course, this type of program is done only once, after which one must select animals on some other basis.

## Study Questions and Suggestions

1. a. What information of value in selecting animals can be obtained by examining the appearance of individual animals?
   b. Of what value is a pedigree for selection purposes if no production records of ancestors are included in the pedigree?
   c. If only one animal four generations back of the one being considered has a really good record, how much can one rely on this record to assure good production by the animal under consideration?
   d. What must one assume about the ancestors of an animal if no production records concerning them are available in the pedigree?
2. a. For traits of high heritability, how important are production records of the animal under consideration?
   b. What safeguard should one consider in evaluating production records?
   c. What is the most accurate method of evaluating the genetic worth of an animal?
   d. For what types of traits is progeny testing most valuable?
3. a. To find an animal of high genetic value about whose performance one can be confident, what two things are needed?
   b. What is family selection and of what value is it?
   c. Can cows and ewes be progeny tested? Why?

### Selected References

Bogart, R. 1959. *Improvement of Livestock.* New York: Macmillan.

# 18. Beef Cattle Breeds and Breeding

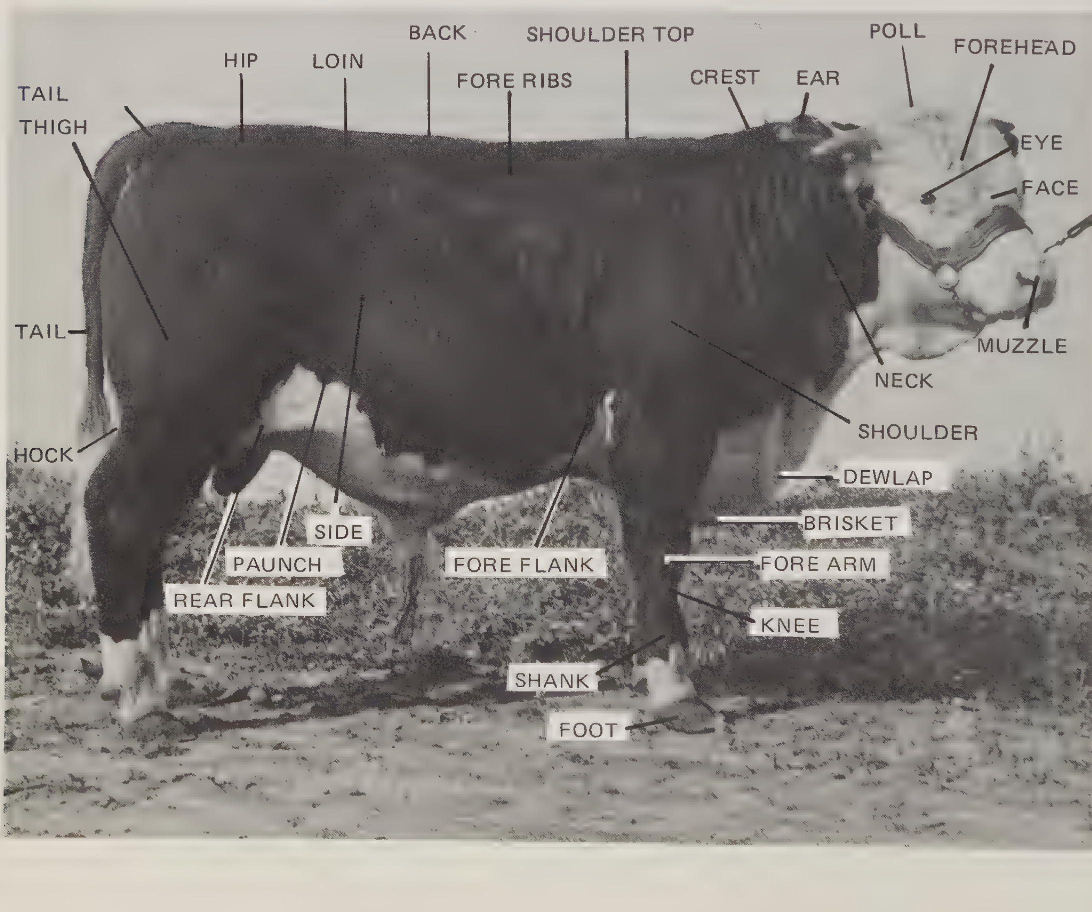
In the early days of beef cattle production in the United States, most of the animals were Longhorns. The use of breeding stock of Hereford, Angus, and Shorthorn breeds to grade up the herds and the straight breeding of these three breeds resulted in marked improvement in the quality of the meat produced. For many years, most of the beef produced in the United States was from grade herds of these breeds. Brahman breeding became important in the South and Southwest. In recent years, several so-called exotic breeds of cattle have been introduced. Many of these breeds are large and muscular and some of them produce fairly large amounts of milk. Some of these breeds were developed where animals were used for work and milk production, and then, when they became old, for beef. These breeds made available to the beef cattle population of the United States germ plasm that was not present in the three British breeds—Angus, Hereford, and Shorthorn.

Almost all of the breeds of beef cattle have some traits, or characteristics, that are important and desirable in beef production, and at the same time have some traits that can be detrimental to beef production in certain situations. It is important to know the characteristics of the breeds so that one can evaluate which breed or breeds will be most effective in beef production in any particular environment and with any particular production scheme.

The parts of the beef animal are shown in Figure 18-2. It is important in discussing animals to know the names of the various parts. The best cuts of beef come from the rib, loin, and rump portions of the live animal (see Chapter 2).

FIGURE 18-1. *Beef cattle are adapted to most parts of the world and to all parts of the United States. They can live on large areas that are not capable of producing plants that people can eat, and they eat roughages that are not edible by people to effectively produce meat that is highly desirable and nutritious. The development, through breeding, of cattle of high productive performance has brought about beef production that today is more rapid and effeicient than in years past.*

FIGURE 18-2. *The external parts of the beef animal.*



## Characteristics of Breeds

Most of the breeds of beef cattle now being used in the United States are shown in Figures 18-3, 18-4, and 18-5. A tabular summary of the productive characteristics for the breeds (Table 18-1) is divided under two headings—traits that can be highly desirable and important in beef cattle production and traits that can be considered undesirable.

## Breeding Beef Cattle

Six important traits (fertility, mothering ability, postweaning rate of gain, feed efficiency, carcass merit, and freedom from inherited defects) must be considered by a purebred breeder who desires to improve beef cattle.

*Fertility* is heritable to but a low degree, so it does not respond rapidly to selection. However, it does respond markedly through crossbreeding. Breeds of cattle differ greatly in fertility, with Brahman cattle having the lowest. The crossbreds, particularly Angus x Hereford crossbreds, are usually very high in fertility. Some inherited endocrine disturbances and some inherited abnormalities of the reproductive tract reduce fertility and sometimes result in sterility. A double cervix is an example of an inherited abnormality that results in reduced fertility. White heifer disease, in which the female tract is incomplete, provides an example of how sterility can result from an inherited abnormality of the reproductive tract. Longevity of reproductive ability is important; consequently, heifers that replace cows that are culled should be daughters of old, productive cows.

*Mothering ability* includes the desire of the cow to care for her calf and her ability to produce milk. We normally consider suckling gain of the calf or its weaning weight as a good measure of the cow's milking ability. Milking ability is an important trait, but whether a cow does or does not lactate to the extent of her inherent ability depends greatly on her diet. Good pastures are extremely important during the suckling period.

*Postweaning rate of gain* is highly heritable and easily measured because all one needs is scales to obtain weight of animals. There is a question as to whether animals need to be fed a diet that is high in concentrates in order that their inherent ability to gain during the postweaning period can be accurately evaluated. Some studies show that feeding a ration that is high in concentrates is not necessary, because animals have been accurately evaluated after they were fed a ration consisting of two parts roughage to one part concentrate. The evidence at present indicates that if feed or pasture conditions are so poor that calves gain less than 1.5 lbs. per day during the postweaning period, their ability to make rapid postweaning rates of gain cannot be evaluated.

*Feed efficiency* is the ability of an animal to convert feed into bodyweight gain. It can be expressed either as the amount of gain made from a unit of feed or as the amount of feed required per unit of gain. It is usually expressed in the latter way. To obtain records on feed efficiency, the animals being studied must be fed individually. *Feed testing* is evaluating an animal's ability to grow and convert feed into body-

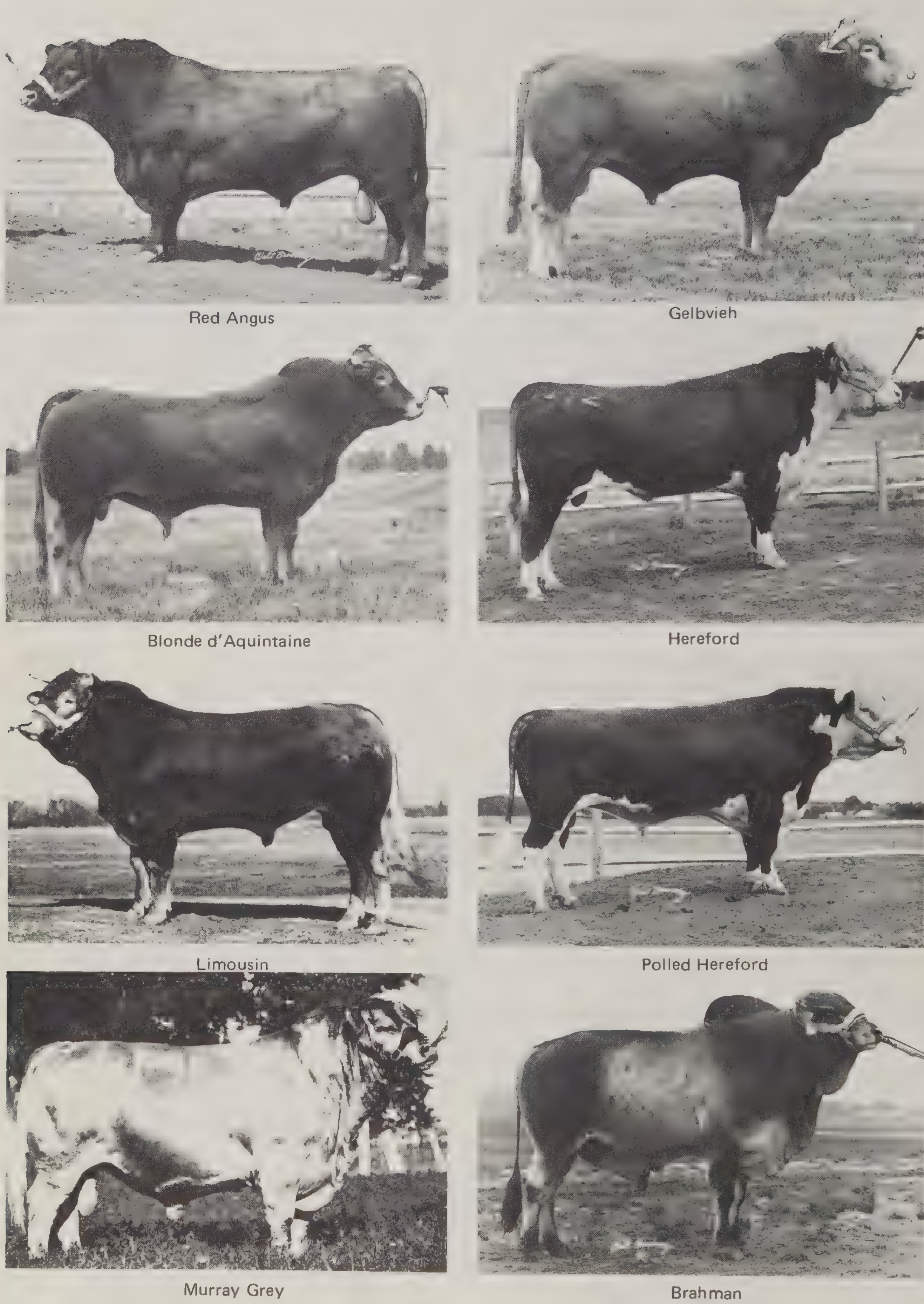


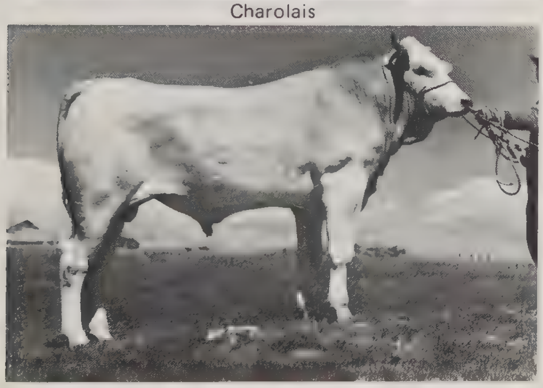

**FIGURE 18-3.** *Some of the breeds of cattle used for beef production in the United States. Courtesy of North American Limousin Foundation, Denver, Colorado (Limousin), American Murray Grey Association, Billings, Montana (Murray Grey), and Curtiss Beef Breeding Service, Cary, Illinois (all others).*

Maine Anjou

Angus

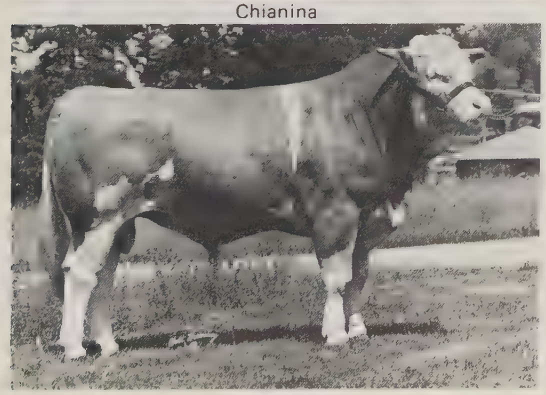
Charolais

Longhorn



Chianina

Brangus



Simmentel

Santa Gertrudis

**FIGURE 18-4.** *Some breeds of cattle used for beef production either as straightbreds or in crossbreeding. Courtesy of USDA (Longhorn) and Curtiss Beef Breeding Service, Cary, Illinois (all others).*

Devon

Scotch Highland

Belted Galloway

Barzona

Shorthorn

Beefmaster

Red Poll

Hays Converter

**FIGURE 18-5.** *Some breeds of cattle used for beef production. Courtesy of USDA (Devon, Shorthorn, Red Poll, and Scotch Highland), Curtiss Beef Breeding Service, Cary, Illinois (Belted Galloway and Barzona), Foundation Beefmaster Association, 200 Livestock Exchange Bldg., Denver, Colorado (Beefmaster), and Mr. Harry W. Hays (Hays Converter).*

## Controlling Diseases and Parasites

The normal temperature of beef cattle is 101.5°F, with a range of 100°F to 103°F. Body temperatures above 103°F should be considered as fever and are indicative of some type of systemic infection. The normal pulse rate is 60 to 70 beats per minute, and the normal breathing rate is 15 to 30 breaths per minute unless the animal has been exercising just prior to the time that rates of pulse and respiration are noted. Sick animals are listless; their head and ears may be drooping; and they may walk slowly and unsteadily.

Several diseases, some of which are discussed below, occur in beef cattle. Some of them may be prevented by vaccination, but all should be avoided if possible by a program of strict sanitation and prevention. Animals should not be introduced into a herd without first isolating them for 40 to 60 days to be certain that they have not been exposed to some disease. One should be certain that the herd from which animals are to be introduced is in good health.

*Red water disease* is usually most prevalent on irrigated or poorly drained areas. This is an acute infectious disease that is called "red water" disease because of the discoloration of the urine voided by affected animals. It can be prevented by inoculation with bacterin or toxoid to stimulate immunity. Treatment is seldom effective. Use preventative measures on those ranches where this disease is present.

*Blackleg* is a highly infectious, fatal disease that is most prevalent in young animals. The first symptom, lameness, is usually accompanied by swelling on the neck, shoulders, flanks, thighs, and brisket. A crackling sound is heard when pressure is applied to the swollen areas. The animal has a high fever. Vaccination prevents the disease in young animals, which will develop a natural immunity. Once blackleg occurs, routine vaccination should be practiced because the premises are contaminated and subsequent outbreaks of the disease are likely to occur.

*Brucellosis* (also called *Bang's disease*) is widespread throughout the world. There are three different types—*Brucella abortus,* which causes abortion of cattle, *Brucella suis,* which is infectious abortion of swine,

and *Brucella melitensis,* which causes abortion of goats. The only definite symptom is abortion unless a blood agglutination test is made and the test proves to be positive.

An eradication program is highly recommended because of the danger of undulant fever in humans, the economic losses in cattle resulting from abortions or stillborn calves, the abnormally high number of retained placentas, and the difficulty encountered in getting females pregnant. The blood of animals can be tested using an agglutination test or a new, rapid card test. The test for brucellosis and the elimination of all reactors should result in a clean herd after a few years, providing that the disease is not reintroduced through purchased animals. In herds where brucellosis is present, one should use calfhood vaccination containing "Strain 19." The calves are vaccinated between the ages of 2 and 9 months. Many states require a negative brucellosis test before allowing animals to enter the state.

*Calf diphtheria* is an acute, infectious disease that affects young animals. Affected animals have difficulty breathing, eating, and drinking because of the dead tissue in the mouth and throat caused by the disease. Affected animals should be isolated from other animals. The dead tissue should be removed. Affected areas should then be painted with tincture of iodine and antibiotics, or sulfa drugs should be administered.

*Calf scours* (also called *white scours* because of the light color of the feces) is highly infectious and often causes death. Little is known about the disease because control methods that are effective in some herds are not effective in other herds. Proper sanitation and disease prevention appear most effective in general. Anti-diarrheal compounds such as kaolin, bismuth, or pectin should be used. Fluids are recommended for calves which are depressed and show dehydration. Administration of antibiotics to infected calves sometimes helps. Calf scours predisposes calves to pneumonia; therefore, antibiotics given to cattle that have calf scours may prevent pneumonia as well.

*Footrot* in cattle causes swelling and soreness just above the hoof and between the toes. Affected animals should be treated early with antibiotic or sulfonamide. Sanitation is extremely important. The use of copper sulfate and/or lime in path areas or on the ground below the bedding of the cattle may help to prevent the disease.

*IBR,* or *red nose,* is caused by a virus. It does not usually cause death, but it does cause animals to have a high fever, to go off feed, and to lose weight. It does not respond to antibiotics and it predisposes animals to other diseases, such as pneumonia. Vaccination prevents this disease; however, pregnant cows should be vaccinated only with intranasal vaccine.

*Johne's disease* is a chronic bacterial dysentery that usually results in death. Affected animals lose flesh and have intermittent diarrhea and constipation. The animal may later have chronic diarrhea in which the feces are watery but not bloody. Animals can be tested with "Johnin" and all reactors eliminated. However, some affected animals do not react when tested and therefore remain to spread the disease. The best way to clean a herd is to move all calves to clean facilities at birth and raise them on milk replacer. The older animals are then eliminated and the facilities are cleaned and left without cattle for a year, after which one can return the young animals to the premises.

*Leptospirosis* is usually a mild disease but it does cause a fever, abortion of pregnant cows at any stage of pregnancy, bloody urine, anemia, reduced appetite, and "ropy" milk. It affects cattle of all ages and both sexes and it also affects humans. It is caused by a spirochete bacterium. Animals can be blood tested and all infected animals eliminated. Vaccination with a bacterin gives protection for a year. Strict sanitation is highly important; in particular, the watering places should be sanitary. Antibiotics may be useful in treating diseased animals.

*Lump jaw* attacks the bones of the head, causing a swelling and soreness that interferes with eating. It is caused by a fungus. The feeding of organic iodine or 50 mg of ethylenediamine dihydriodide (EDDI) per head daily may help to prevent the disease. Treatment of infected animals with 250 to 500 mg of EDDI daily for 2 weeks is usually effective. If the jaw ruptures or becomes soft and is lanced, one should treat it with a strong iodine solution.

*Pinkeye* is an infectious disease affecting the eyes. Cattle should be observed closely for watering of the eyes, and treatment should be started early. The eye can be treated with crystal violet, and antibiotics can be injected into the inside of the upper and lower eyelids. Injection of a foreign protein, such as milk, is used by some to create a reaction against pinkeye. If left untreated, the disease may cause loss of sight. Animals that are suffering from pinkeye become unthrifty.

*Pneumonia* is an inflammation of the lungs. It is usually secondary to some other disease or condition that reduces the resistance of the animal. The lungs may discharge fluid and the animal shows labored breathing and has a high fever. The sick animals should be isolated, kept in a comfortable place, and given antibiotics and/or sulfa drugs. Because pneumonia acts rapidly, one should start treatment early, using injected antibiotics rather than oral administration.

*Shipping fever* is an acute respiratory disease that usually occurs following a stress condition; therefore, calves should be closely observed following weaning or transportation to feedlots. Stress interacts with viral agents and bacteria to cause shipping fever. Affected animals have a high fever, show a discharge from the nose, and cough a great deal. They have difficulty in breathing. Preconditioning of calves should be practiced to reduce incidence and severity. Preconditioning includes recovery from weaning, castration, and dehorning prior to sale of the calves. It also includes worming and vaccination for blackleg and viral diseases. The calves are fed hay and grain prior to shipment so that they go into the feedlot properly adjusted.

*Tuberculosis* in cattle is a chronic disease that can also be controlled by testing and eliminating all reacting animals. The tuberculin testing is done either intradermically (within the skin), subcutaneously (under the skin), or ophthalmically (in the eye). The test is usually intradermic. Affected animals react to the injected material by swelling at the site of the injection.

*Vibrio fetus* is an infection of the reproductive tract and results in abortion in the middle one-third of pregnancy. It can also cause irregularity of cycles and difficulty in getting cows pregnant. It is transmitted by coitus; therefore, the spread of this disease is prevented by artificial insemination. A vaccine is available for use in cattle. Proper sanitation, which includes isolating a cow that has aborted, burning the

fetus and membranes, and thoroughly cleaning and disinfecting the area where the abortion occurred, helps to prevent the spread of the disease.

*Warts* are infectious small tumors on the skin that are caused by a virus. The warts are treated with oil to soften the tissue, after which they may be removed and the wound treated with iodine. Some people use wart vaccines. Warts are not usually highly detrimental to the health of animals, but they are unsightly.

Several parasites, including larvae of screw-worm flies and heel flies, affect cattle. *Screw-worms* differ from maggots in that they eat into normal, living flesh, whereas maggots live on the rotting material of a wound. Both must be eliminated because screw-worms eat deeply into flesh, and maggots irritate the animals severely. Sacks with an insecticide dust can be made available in such a way that the cattle rub them, causing the insecticide dust to be deposited on the animal. This dusting helps to control flies. *Heel flys* lay eggs on the legs. These eggs hatch into larvae that penetrate the skin. By the next spring, the larvae, now called warbles, have become embedded just under the skin on the back and sides of the animal. The warble cuts through the hide, thus reducing the value of the hide, and creates a carcass that needs trimming. It emerges and soon becomes an adult. One can use a systemic insecticide to kill warbles. The insecticide is usually given in early October; however, the time most effective for administering the insecticide varies with climatic conditions.

Cattle also have *lice* and *mites.* One can dip, dust, or spray cattle for the control of these parasites. At least two properly spaced sprayings or dippings are usually required because the eggs are not killed by these applications. Thus, one destroys only those larvae that have hatched with the first application and must therefore destroy those that hatch later with the second application.

Cattle are subject to *stomach worms* and *bowel worms.* Pasture improvement and irrigation allow us to concentrate cattle, which increases the losses to parasites. Use pasture rotation and regular treatment schedules to limit these losses. Several antihelmintics are commercially available for worming cattle.

# 20. Dairy Cattle Breeds and Breeding

Six major breeds of dairy cattle (Holstein, Ayrshire, Brown Swiss, Guernsey, Jersey, and Shorthorn) are used for milk production in the United States.

## Characteristics of Breeds

Table 20-1 summarizes the production characteristics of the breeds listed above and gives other information about them. The breeds are shown in Figure 20-2.

The average "productive life" of a dairy cow is short (approximately 3 years), because many cows must be culled due to lack of fertility and udder breakdown. Some cows are culled because of low production; a few become injured; losses occur occasionally from natural death. By far the greatest number of dairy cows leave the herd because of udder problems and because of failure to become pregnant. Holstein cows produce extremely large amounts of milk—many of them produce up to 100 lbs. per day at the time of peak lactation. Thus, in Holstein cows, great stress is placed on the udder, which can, as a result, break down. Thus, udder problems are more prevalent in Holsteins than in the other breeds. Ayrshires and Brown Swiss produce milk for a long period of time, but their production levels are not high considering their large size.

Guernsey and Jersey cows produce milk having high percentages of milk fat and solids-not-fat, but the total amount of milk produced is relatively low. The efficiency of energy production of the different

**Table 20-1. Characteristics of the breeds of dairy cattle.**

| | *Holstein* | *Ayrshire* | *Brown Swiss* | *Guernsey* | *Jersey* | *Shorthorn* |
|---|---|---|---|---|---|---|
| Origin | Holland | Scotland | Switzerland | Guernsey Island | Jersey Island | England |
| Weight | | | | | | |
| Male | 2,200 lbs. | 1,850 lbs. | 2,000 lbs. | 1,600 lbs. | 1,500 lbs. | 2,000 lbs. |
| Female | 1,500 lbs. | 1,200 lbs. | 1,400 lbs. | 1,100 lbs. | 1,000 lbs. | 1,400 lbs. |
| Color | Black and white | Mahogany and white spotted, may have pigmented legs | Solid blackish; hairs dark with light tips | Light red and white, yellow skin | Blackish, hairs have white tips to give gray or red tips to give fawn solid or white spotted | Red, roan, or white, or red and white or roan and white |
| Milk yield | Very high | Intermediate | Intermediate | Low | Low | Low to intermediate |
| Percent fat | Very low (3.7%) | Intermediate (4.2%) | Intermediate (4.2%) | High (4.9%) | Very high (5.4%) | Low to intermediate (3.9%) |
| Udders | Very large; problems with udder breakdown | Large, strong | Large, strong | Medium size, strong | Small, strong | Large, strong |
| Longevity of production | Low | Good | Outstanding | Intermediate | Intermediate | Intermediate to good |

breeds does not vary among the breeds as much as either total quantity of milk produced or percentage of fat in the milk.

Great strides have been made in improving milk production through improved management and breeding. For example, the amount of milk produced in the United States in 1975 was about the same as that produced in 1945, yet the number of dairy cows in 1975 was less than half the number in 1945. Thus, the average production per cow in 1975 was more than double that in 1945. One other point is that consumption of milk in 1975 per person per year probably is less than it was in 1945 because more people in 1975 consumed about the same total amount of milk that was consumed by fewer people in 1945. More milk was used for feeding young calves in 1945 than is presently used for that purpose.

In the past, dairy operators have placed great emphasis on "dairy type" (a cow of ideal dairy type would have refinement, well-attached udders, prominent milk veins, and strong feet and legs), but recent studies indicate that many of the components of dairy type are negatively related to milk production. Unless dairy type of the young animal is predictive of subsequent production or of productive life of a dairy cow, dairy type has little or no value and might even be deleterious if overstressed in selection. A properly attached udder and strong feet and legs may indicate how long a cow will remain a high producer. The external parts of the dairy cow are shown in Figure 20-3 to clarify the location of important parts of the body.

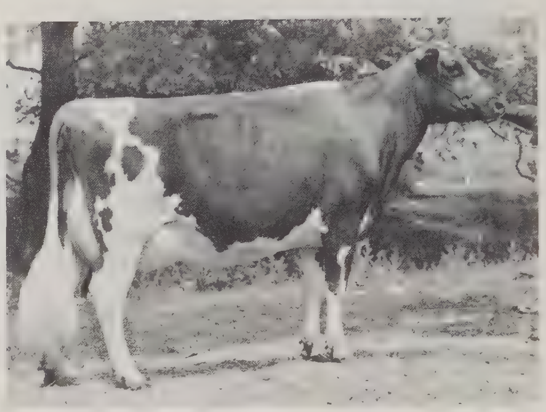
Certainly as more dairy cows are housed on hard floors, difficulties in maintaining healthy feet and legs may be expected to increase unless selection for strength in feet and legs is practiced. Perhaps the best evaluation of a dairy cow is the amount and quality of milk that she produces. Because protein is the most important component of milk for

**FIGURE 20-1.** *The dairy cow could be considered a foster mother because many human babies have started early life by consuming cows' milk from a bottle. Milk is probably the most important food in nutrition, particularly for young people. Production of milk per cow has been increased markedly in the past 40 years by improvements in breeding, feeding, sanitation, and management. Courtesy of Dr. R. W. Henderson, Oregon Agricultural Experiment Station.*

Jersey

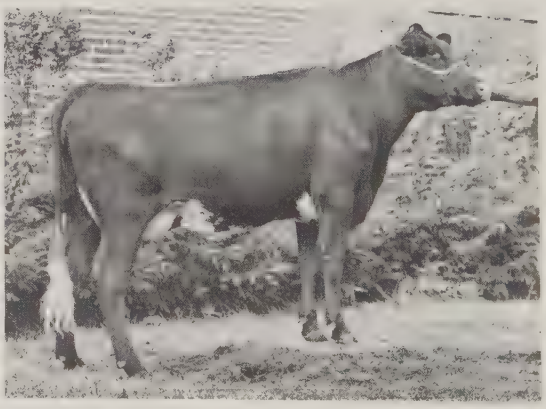
Holstein

Guernsey



Ayrshire

Brown Swiss



Milking Shorthorn

**FIGURE 20-2.** *Major breeds of dairy cows used for milk production in the United States. Photograph of Jersey cow courtesy of Hoard's Dairyman. Other photographs courtesy of Agri-Graphic Services, Cary, Illinois (Danny Weaver and Jim Miller, photographers). Composite photograph by Dr. R. W. Henderson, Oregon Agricultural Experiment Station.*

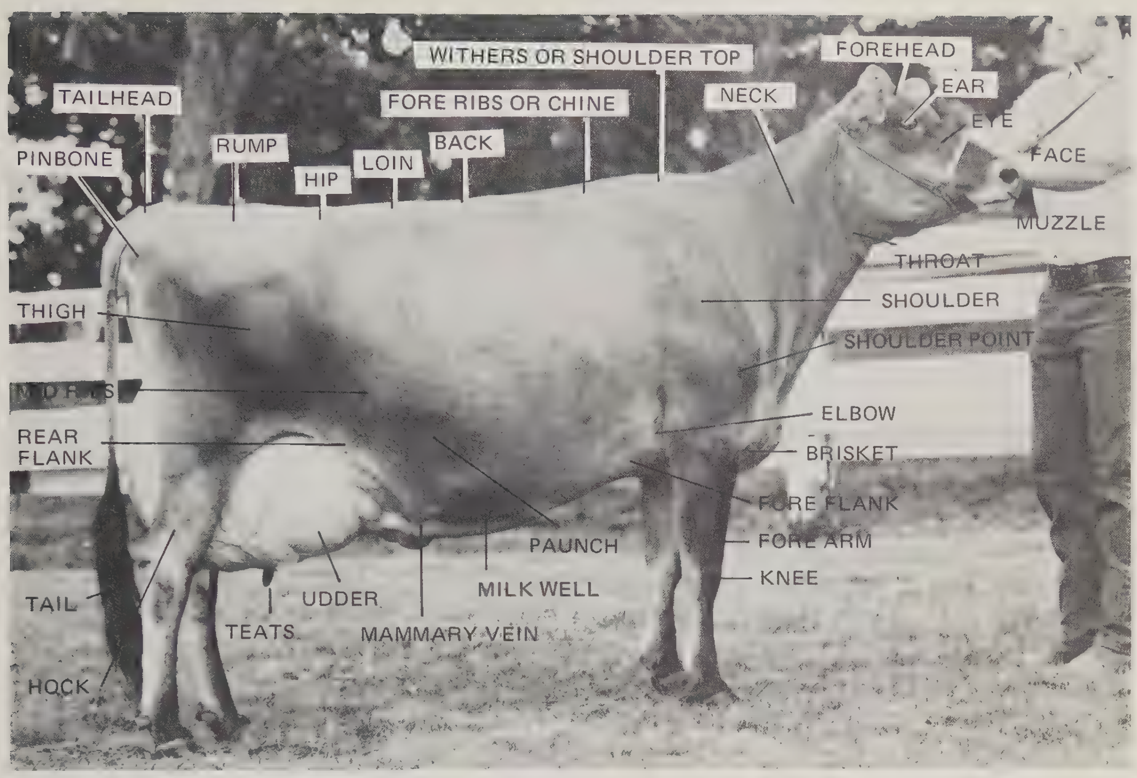



FIGURE 20-3. *The external parts of the dairy cow. Courtesy of Hoard's Dairyman.*

human nutrition, rate and efficiency of protein production should become increasingly important for evaluating dairy cows.

A registry association for purebred animals exists for each of the breeds of dairy cattle in the United States. In addition, there are selective registries which honor cows with outstanding production performance and bulls with daughters that are outstanding in production. For example, the Holstein selective registry has the "gold medal dam" and the "gold medal sire" awards. A gold medal cow must produce 100,000 lbs. of milk or must produce an average of 12,500 lbs. of milk per year plus 500 lbs. of milk fat per year; and she must score 80 points as a 2- or 3-year-old, 81 as a 4- or 5-year-old, and 82 at 6 years of age or older on the basis of 100 points for perfection when points are accumulated on a score card for scores assigned to the various parts of the animal. The gold medal cow should also have three daughters that meet the above requirements in milk production and three male or female offspring that meet the classification (score) standards. A gold medal sire must have 10 or more daughters that produce 13,000 lbs. of milk or more per year and 585 lbs. of milk fat or more per year. Each of these daughters should score at least 82 points in classification. Other breed associations have selective registries as a means of encouraging improvement in production.

## Controlling Diseases

Several diseases, such as tuberculosis and brucellosis, can affect dairy cattle. Cattle can be tested for these diseases; all animals that are reactors are removed. If one does not introduce any animals into the herd from other herds, but instead breeds the females through artificial insemination and raises the replacement heifers, tuberculosis and brucellosis would not occur once a clean herd has been established.

Perhaps the most troublesome condition in dairy cattle is mastitis. Any inflammation (swelling and reddening) is referred to by naming the part affected and adding "-itis." Thus, "mast-" (referring to the mammary gland) with "-itis" added is *mastitis,* which means a swelling of the udder or mammary gland. Mastitis in its early stage of development causes small white clots to occur in the milk. To locate a cow with beginning mastitis, one collects milk using a strip cup which has a fine screen on a dark background so the white clots are collected and can be seen. As mastitis progresses, the milk shows white strings; this milk is called "ropy" milk. The signs of this stage of mastitis are obvious; the udder is swollen, red, and hot, and gives pain to the cow when touched. In the final stages of mastitis, the strings of ropy material become dark and are present in a watery fluid. At this stage the udder has been so badly damaged that it no longer functions properly.

Susceptibility to mastitis is genetically controlled, but many environmental factors can trigger its development. Bruises, improper milking, and unsanitary conditions where the cows are kept all encourage the development of mastitis. Unfortunately, high-producing animals are more likely to injure their udders than low-producing animals. Also, cows with pendulous ("hanging down") udders are more likely to develop mastitis, and the udders of high-producing cows are often pendulous. Prevention of mastitis by good management is highly recommended, because treatment is costly. Milk from a mastitic udder cannot be put into salable milk for human consumption. One can treat the udder by inserting a tube through the teat into the udder cistern and depositing antibiotics there. Milk from a cow treated with antibiotics must not be immediately sold for human consumption. Depending on the antibiotics used, milk is usually withheld for 2 to 4 days after the cow is treated with antibiotics. A mastitis attack always destroys some tissue of the gland and reduces the amount of milk produced. It is generally recommended that udders be treated when cows are not lactating.

Dairy cattle are affected by the same diseases and parasites that affect beef cattle; therefore, the discussion of diseases and parasites of beef cattle (see Chapter 19) is applicable to dairy cattle.

# 22. Swine Breeds and Breeding

Several well-established breeds of swine are raised in the United States. In addition, some breeds developed within the last 40 years, such as the Minnesota No. 1, No. 2, and No. 3, have a place in swine production. Most market hogs are crossbred, but purebred animals, especially production-tested boars, are the seedstock herds that produce the crossbreds.

## Characteristics of Breeds

The well-established breeds and their characteristics are listed in Table 22-1. Representatives of these breeds are shown in Figure 22-2. The newly created breeds were established by crossing existing breeds and selecting primarily for production traits. Following the crossing of the breeds, the attempt was made to combine desirable traits of existing breeds and to eliminate undesirable characteristics through selection in a closed population. Some of the newer breeds were superior to some of the older, established breeds, but it was not possible to develop a breed that would perform better than crossbred animals when a well-planned crossbreeding program was followed.

Several years ago, swine were classified as lard type or bacon type. Duroc, Chester White, Hampshire, Spotted, Poland China, and Berkshire breeds were considered lard type. Yorkshire, Landrace, and Tamworth were examples of bacon type. During the past 20 years, selection of all breeds for the production of lean meat has reduced the differences among breeds and between the two types. Even so,

**Table 22-1. Breeds of swine and their characteristics.**

| *Breed* | *Superficial traits and colors* | *Udders and fertility* | *Rate of gain* |
|---|---|---|---|
| Hampshire | Black with white belt; nervous | Average litter size; good udders | Average |
| Duroc | Red | Good litter size | Excellent |
| Poland China | Black, six white points—on feet, tail, and snout | Small litter size | Good |
| Spotted | Black and white spotted | Average litter size | Good |
| Berkshire | Black, six white points, erect ears | Small litter size | Average |
| Yorkshire | White, erect ears | Very large litter size; good mothers | Average |
| American Landrace | White | Very large | Average |
| Chester White | White | Good litter size | Average |
| Tamworth | Red | Small to average litter size | Low |

**NOTE:** Generally the Hampshire and Poland China breeds are noted for large loins and the Yorkshire and American Landrace breeds are noted for their high fertility. At one time the Duroc and Chester White breeds were somewhat fat and the Berkshire and Yorkshire hogs had turned-up snouts; however, these undesirable features are being eliminated through rigid selection programs. At the present time highly desirable hogs are present in each of the breeds.

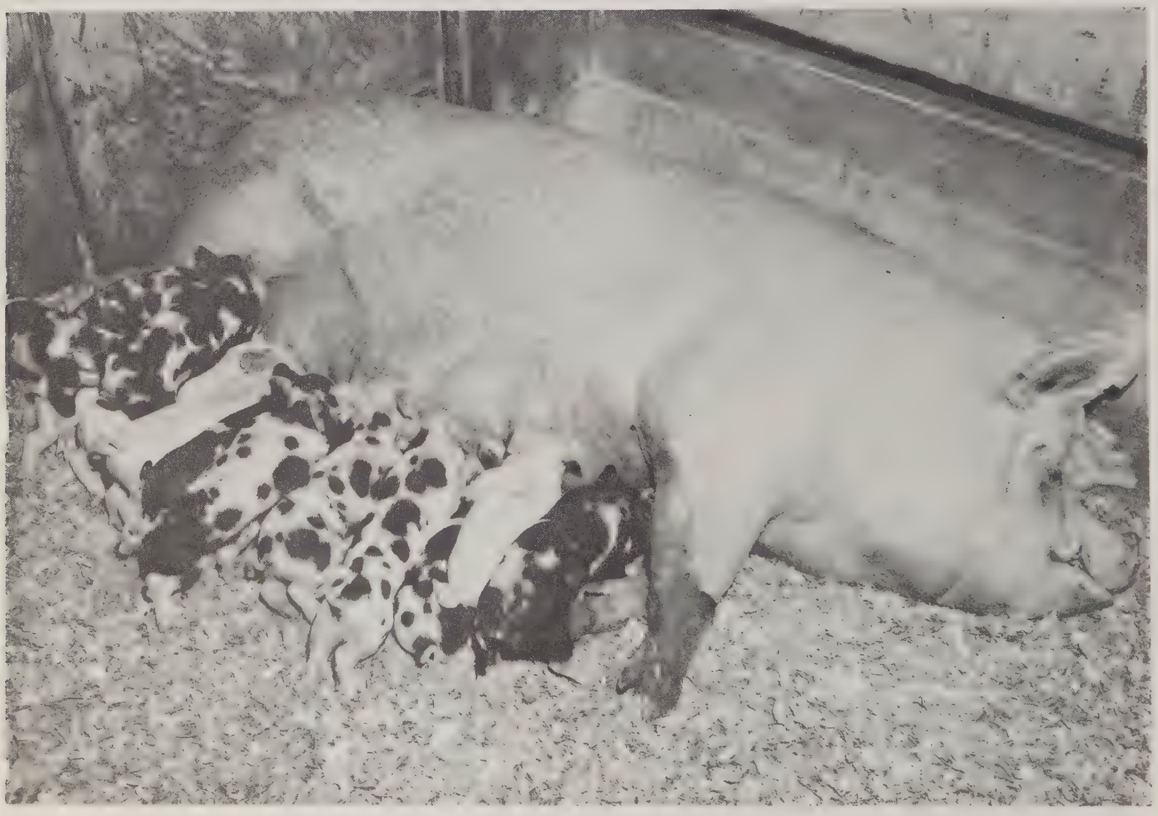


FIGURE 22-1. *Crossbred sow with her litter of 17 pigs. The 17 pigs weighed a total of 52 lbs. at birth. This sow raised 15 of her pigs. Swine production is centered in the corn-producing (Midwest) region of the United States. One of the most important aspects of swine production is the production of large litters. Crossbred sows producing crossbred offspring are generally outstanding in pig production. Although hogs need a high proportion of concentrate feeds, they are sustained largely on corn rations that are properly supplemented with protein. Thus, hogs consume grains that are not eaten in large amounts by people. Courtesy of Dr. D. C. England, Animal Science Department, Oregon State University.*

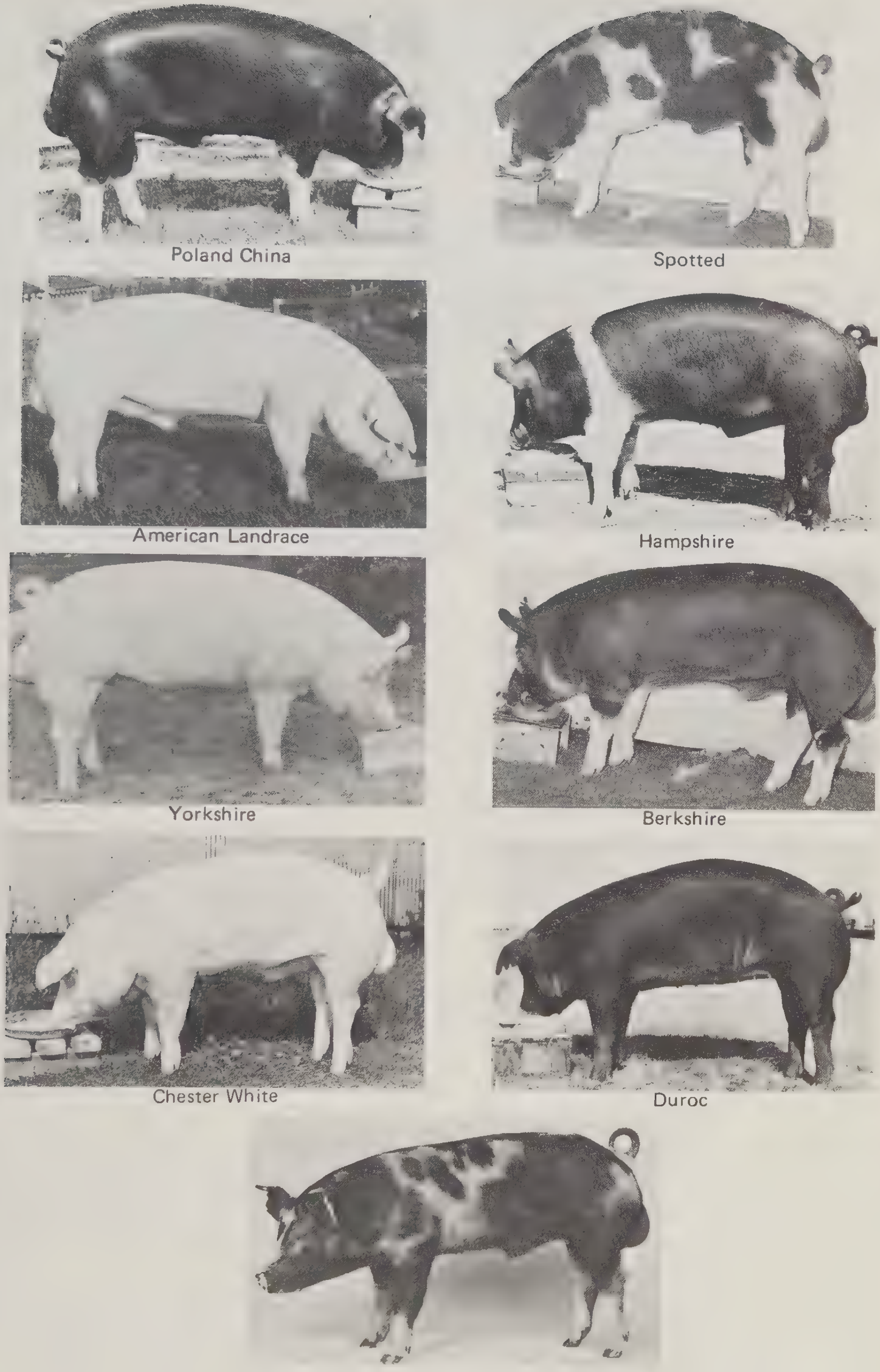



**FIGURE 22-2.** *The major breeds of swine in the United States. Note that breeding for meat type in the past 20 years has made the breeds appear similar except for color markings. Courtesy of Poland China Record Association, Galesburg, Illinois (Poland China), National Spotted Swine Record, Bainbridge, Indiana (Spotted), American Landrace Association, Culver, Indiana (American Landrace), USDA (Hampshire and Chester White), American Yorkshire Club, West Lafayette, Indiana (Yorkshire), American Berkshire Association, Springfield, Illinois (Berkshire), United Duroc Swine Registry, Peoria, Illinois (Duroc), and Boar Power (boar/gift breeding system by Monsanto), Des Moines, Iowa (typical hybrid boar).*

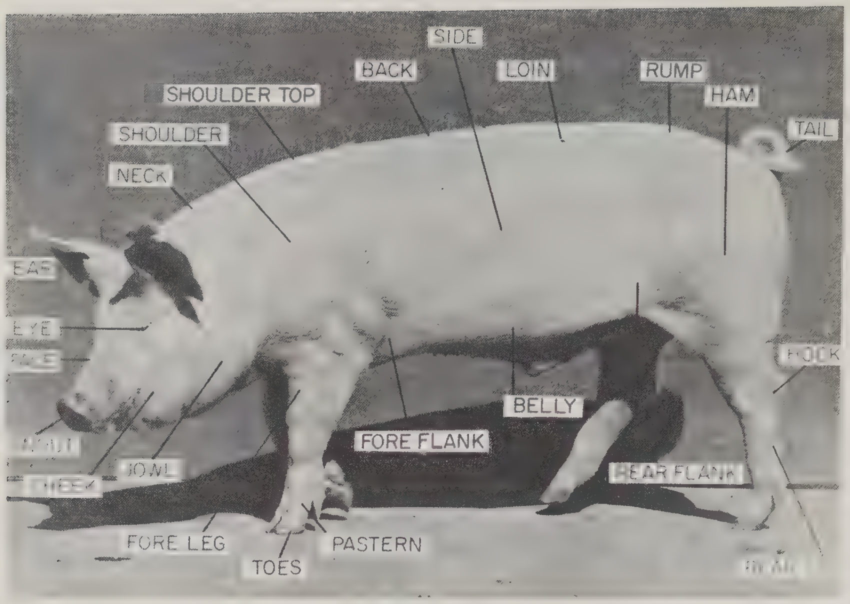



**FIGURE 22-3.** *The external parts of the hog. Courtesy of Dr. D. C. England, Animal Science Department, Oregon State University.*

differences among the breeds still exist in level of fertility, rate and efficiency of gains in weight, and certain carcass characteristics.

Swine have shown marked responses to selection for type. Years ago, most hogs were "cob-rollers" or "hot-bloods," because consumers wanted large amounts of lard and ate meat that was quite fat. At that time, people did hard physical labor for many hours per day which required much energy. The use of mechanization instead of hand labor and the substitution of plant fats for lard as shortening compounds have markedly reduced the need for lard. Swine producers, as a result, moved away from the short, thick "cob-rollers" to large, long, and upstanding hogs that were not ready for slaughter until they weighed 300 lbs. or more.

When swine breeders switched to selection for production of lean meat, they developed the present-day pig, which is high in lean, long in body, plump in the ham, and clean in the jowl. These swine are classified as meat type and are slaughtered at 200 to 240 lbs. live weight. They make excellent carcasses.

Color has value in swine even though there is no difference in meat quality or performance among the different colors of pigs. White pigs may sunburn severely when exposed to summer sunshine, but this is not a serious hindrance to production. White is dominant to colored and epistatic to all colors and color combinations.

The external parts of the hog are shown in Figure 22-3. It is important to know the names of the parts of a hog. The ham, loin, side, and shoulder of the live hog contribute valuable wholesale cuts.

## Breeding Swine

Swine differ from most other farm animals in several respects:

1. They bear litters, in contrast to sheep, cattle, and horses.
2. In the United States, they are used for meat production only.
3. They have a short gestation period (114 days), short suckling

## Controlling Diseases and Parasites

Many diseases and parasites affect swine. Most of these are best controlled by vaccination, proper sanitation, and prevention programs. Clean, sanitary conditions where pigs are kept and the prevention of introduced diseases and parasites do much to reduce the occurrence of diseases and parasites of swine. Diseases and parasites not only cause losses from death, but can cause even greater losses by reducing the production of the animals. In addition, diseases and parasites mask inherent differences existing among animals so that the effectiveness of selection is markedly reduced.

Many swine producers have adopted a specific-pathogen-free (SPF) method of swine production. To initiate such a herd, baby pigs are delivered by Caesarean operation. The pigs are developed under conditions of strict sanitation and management away from other hogs. All other hogs are disposed of, and the swine facilities are completely and thoroughly cleaned and left empty for 6 weeks or more before "clean" animals are brought into them. The herd is closed to the introduction of any other hogs with the exception of animals that are obtained from a certified specific-pathogen-free herd. Once the herd is established, reproduction occurs in the normal way. New germ plasm can be introduced by artificial insemination.

**External and internal parasites.** The two most common external parasites are *lice* and *mites.* Mites cause itching and scab formation on the skin. Both lice and mites can be controlled by spraying hogs with an effective insecticide, preferably one with a residual action that will kill parasites as they hatch from eggs. Insecticides usually do not kill parasites that are in the egg stage. Insecticide usage is subject to government regulations and these regulations must be closely followed. Fleas, flies, mosquitoes, and ticks also attack swine. A good control program for lice and mites in which an insecticide with residual action is used also controls these parasites.

Internal parasites that commonly infest swine include large roundworms, lungworms, nodular worms, kidney worms, whipworms, and trichina worms.

The *Ascaris* roundworm is perhaps the most serious internal parasite. The eggs of ascarids are eaten by hogs and hatch in the small intestine.

The larvae then bore into the gut lining and enter blood vessels through which they are carried to the liver. The larvae travel by the blood vessels to the lungs. The larvae develop in the lungs, migrate to the trachea, and are swallowed. The worms locate in the intestines, where they produce many eggs that are passed with the feces. Symptoms include coughing when the larvae are in the lungs and trachea, failure to gain weight, lack of appetite, and, often, a fever. Diagnosis of roundworm infestation is made by examination of the feces for eggs.

Control of roundworms includes proper sanitation and treatment with a vermifuge (a chemical that kills worms). Dichlorvos is an effective vermifuge because it kills many other internal parasites. It also kills both the larvae and the adult ascarids. It can be administered with the feed.

*Lungworms* are parasites of the respiratory and circulatory systems of pigs. Earthworms are the intermediate hosts for lungworms. Adult lungworms live in the lung; their eggs are coughed up, swallowed, and passed in the feces. The eggs are ingested by earthworms, in which a series of larval stages occurs. When pigs eat earthworms, the freed larvae penetrate the intestinal wall and go into the lymphatic system and later into the bloodstream. They are carried by the blood to the lungs. Symptoms include severe coughing, difficult breathing, and lack of appetite. Control of lungworms includes the use of clean pastures (pasture rotation). Lungworms are not likely to infest pigs that are raised in confinement without contact with earthworms. The infective larvae of *nodular worms* that are swallowed by foraging swine burrow through the lining of the large intestine of swine to form nodules, thus allowing for secondary infection of the gut. Afflicted pigs show signs of depression, lose weight, have a reduced appetite, and do not grow well. The only way to definitely diagnose nodular worms is by autopsy. Eggs from nodular worms appear in the feces of infested pigs but are difficult to differentiate from eggs of certain other parasitic worms. Strict sanitation should be used to prevent infestation. A veterinarian should be employed if a severe infestation occurs in the herd.

Because the *kidney worm* has a migratory phase, larvae may be found in almost any organ. Larvae are usually found in the liver, fat around the kidneys, and ureters (tubes leading from the kidneys to the bladder). Larvae migrate by way of the bloodstream. The earthworm serves as an intermediate host for the kidney worm; therefore, pigs raised in total confinement are not likely to become infested if the facilities are kept clean and sanitary. If hogs are on pasture, one should attempt to have feeders and waterers on dry areas. Infested pigs can be treated with Thibenzole. The eggs of kidney worms are voided through the urine. They hatch and are eaten by earthworms, after which pigs eat the earthworms and become infected. Young pigs affected with kidney worms usually grow slowly and digest feed inefficiently. Young pigs that have severe infestations may lose weight rapidly and die. Diagnosis is based on finding eggs of kidney worms in the urine.

The *whipworm* of swine may affect both people and monkeys. Whipworms affect the cecum and colon. Afflicted animals grow slowly, have a rough hair coat, and digest feed inefficiently. Diagnosis is based on finding eggs of this parasite in the feces. The best control is prevention by strict sanitation. Infested pigs can be treated with Dichlorvos with reasonable success.

Swine *trichina worm* is found mainly in the pig and causes a disease called trichinosis in humans. The trichina larvae embed in the muscles of pigs. They do not usually cause any symptoms in naturally infected pigs. When muscle tissue of infected pigs is examined, cysts containing live larvae are observed. These cysts with live-larvae may remain intact for years in the muscles but usually calcification of the cysts occurs, which causes the larvae to die.

Humans contract trichina infection by eating uncooked or improperly cooked pork products. Hogs fed uncooked garbage show much higher infestation of trichina than those fed grain rations or cooked garbage; therefore, garbage should be thoroughly cooked if it is to be fed to swine. Educating the public to the necessity of properly cooking pork products to a temperature of at least 137°F will prevent the transmission of trichina from pigs to humans.

**Common diseases of swine.** Some of the common diseases that affect swine are discussed below.

*Atrophic rhinitis* is an atrophy (often rotting) of the tissues of the nasal sinuses. It is best controlled by raising specific-pathogen-free hogs. If this disease is not present in the herd, care should be taken to prevent its introduction when breeding stock is purchased. Obtaining boars from certified specific-pathogen-free herds is good assurance of not introducing the disease. Although antibiotics and sulfa drugs can help eliminate the disease, one is better advised to go to a specific-pathogen-free operation.

*Brucellosis* not only affects swine, but the organism that causes brucellosis in swine can seriously affect humans by causing undulant fever. The herd can be tested for brucellosis and any reactor removed from the herd. If brucellosis is present, it can be brought under control by using only young boars and gilts for breeding, allowing only one service, and disposing of all females that return to heat. Boars can emit the organism that causes brucellosis through their semen. One should wear rubber or plastic gloves when collecting semen and handling newborn pigs if reactors to brucellosis are found in the herd. There is no effective treatment for brucellosis.

*Swine erysipelas* is a bacterial disease that occurs either as an acute or a chronic form. Vaccination with bacterin, along with proper sanitation, is an effective control. Because this disease can affect humans, caution should be used. The acute form can cause death of many animals. Greater economic losses may occur, however, with the chronic form. Hogs afflicted with chronic erysipelas do not die but eat feed without making normal growth and thus become exceedingly costly to maintain. Erysipelas usually affects pigs that are less than a year old. Afflicted animals have a fever, have a reduced appetite, and move stiffly. Skin lesions or red patches may occur along the ears and down the back. These lesions often are diamond-shaped. The affected skin may die and slough. Because dogs, cats, and rodents may carry the disease, these animals should be eliminated from the swine unit.

*Greasy pig disease (exudative dermatitis)* affects young pigs. Afflicted pigs become listless and have a droopy appearance. A dandrufflike condition of the skin later appears. At this time, the pigs are restless. Three forms of exudative dermatitis are known: peracute, acute, and subacute. In the peracute form, the skin of the whole body is covered with moist,

greasy exudate. Death usually occurs in 3 to 5 days. In the acute form, the skin becomes thickened and wrinkled. Death may occur in 4 to 8 days. In the subacute form, death occurs at a lower rate. There is no known cure for this disease. Surviving animals develop an immunity; therefore, it is unlikely that outbreaks in successive farrowings will occur.

*Gut edema* is characterized in young feeder pigs by subcutaneous edema, paralysis, and high mortality rate. If pigs afflicted with this disease do not die within 5 days, it may be assumed that the disease has run its course. Swelling of the eyelids, snout, face, and jowl occurs in afflicted pigs. Body temperature usually remains normal. Usually only a small percentage of the animals in a herd will be affected, but the death rate of afflicted animals is high (90%). Accurate diagnosis is based on autopsy observations of edema in wall of stomach, mesentery, and the large bowel. Unfortunately, the most rapidly gaining pigs are the most susceptible. Avoiding stresses to pigs helps to prevent an outbreak of the disease. The amount of feed allowed afflicted pigs should be substantially reduced to empty the intestinal tract, after which feed intake should be gradually increased.

*Hog cholera* is caused by a virus. It has been a serious disease of swine in the United States. The national hog cholera eradication program has effectively eliminated the disease from this country. An outbreak can be controlled by use of antisera and immunity can be established by use of attenuated viruses and antisera.

*Leptospirosis* affects many species of animals, both domestic and wild. In swine, it causes large losses of baby pigs through abortions and stillbirths. In addition, affected sows may farrow weak pigs. Several forms of the disease are known but only one, *Leptospira pamona,* can be accurately diagnosed. Vaccination is effective in the control of *Leptospira pamona.* The most important signs of the disease are abortions, stillbirths, and the occurrence of small, weak pigs. Accurate diagnosis for *Leptospira pamona* can be made by serotyping.

The only practical way to deal with leptospirosis is prevention by vaccination. Treatment of infected animals with antibiotics is effective but usually the damage has been done in the herd by the time diagnosis is complete.

*Mastitis-Metritis-Agalactia (MMA complex)* is a complex of three maladies that occur in association with one another. (Mastitis is inflammation of the udder; metritis is inflammation of the uterus; and agalactia is absence or failure of the secretion of milk.) Several body organs may be affected, but the causative streptococcus and staphylococcus bacteria are most commonly found in the uterus and mammary glands. There may be a purulent discharge from the vulva in late pregnancy or early in lactation. Mastitis usually develops in early lactation. Pigs nursing from affected udders may develop diarrhea. Milk production is markedly reduced.

Prevention and treatment are difficult because MMA complex is a complex of maladies. The presence of high levels of antibiotics in the diet in the last 3 weeks of pregnancy decreases the severity of the syndrome. Proper sanitation is extremely important in the preventing the occurrence of MMA complex.

*Mycoplasmal pneumonia* is a chronic respiratory disease. It is characterized by a dry, persistent cough and decreased growth rate. Young

pigs are most susceptible but older animals may contact the disease and become carriers. Relatively few deaths result from this disease, but affected pigs grow slowly and digest feed inefficiently. The disease is spread by air droplets and by direct contact with affected pigs.

Once a severe outbreak has occurred, one can eliminate all hogs and cleanse the facilities, after which a specific-pathogen-free program is initiated. One can save desirable breeding stock by taking newborn pigs away from their mothers and raising the young pigs in isolation on milk replacer. Later the older stock is eliminated and the facilities are thoroughly cleaned. The pigs raised in isolation can then be introduced into the facilities. A person whose herd is clean is well advised to operate the herd as a closed herd so that the disease is not introduced.

*Salmonellosis* is produced by any of hundreds of known *Salmonella* serotypes, but only two of these bacterial organisms appear to affect hogs. Young weanling pigs may be found dead after having showed no previous signs of illness. If stress conditions are minimized and good sanitation is practiced, losses from salmonellosis can be kept low. Pigs may have a high fever and show depression, and the skin of ears and inner thighs may become reddened. The chronic form may result in scouring. Pigs may recover but they will be greatly stunted. Some apparently normal hogs are carriers of the disease-causing organism. Acute or chronic types of salmonellosis are known.

The nitrofurans (Furazolidone-NF 180) apparently give good results in the treatment of salmonellosis. Some of the wide-spectrum antibiotics such as neomycin are also somewhat effective against *Salmonella* and also against the bacterium *Escherichia coli,* whose presence may complicate the *Salmonella* infection. Good sanitation, proper feeding and management, and the prevention of severe stresses help to prevent outbreaks of salmonellosis.

*Swine dysentery* is a common infectious disease of swine which causes changes to occur in the large intestine that lead to a form of diarrhea in which digestive wastes are usually bloody and contain mucus. Dysentery occurs most commonly in pigs that are 7 to 12 weeks old. As many as 80% of the pigs in a herd may die in an outbreak of dysentery; losses as high as 100% have been documented. The first sign of dysentery is the appearance of soft, yellow feces. The diarrhea that occurs causes dehydration and weight loss. As the disease progresses, scouring is more severe and feces become dark and watery due to the presence of blood in them. The animals become dehydrated, weak, and depressed. The disease is usually introduced into a herd by newly introduced animals. No outbreak of the disease should occur in a closed herd.

Good sanitation, the use of closed-herd breeding, the introduction of breeding stock from specific-pathogen-free herds, and the introduction of sperm by artificial insemination all help to prevent this disease.

*Swine influenza* is characterized by sudden onset, coughing, fever, and rapid recovery. It is caused by infection with two agents, influenza virus and a bacterium (*Hemophilus suis*). It affects the upper respiratory tract (trachea and bronchi), but drainage may carry it into the lungs. It usually occurs suddenly—most of the pigs in a herd are affected within a few days. Both causative agents are present at all times; therefore, a sudden outbreak of influenza indicates the presence of some stress condition that encourages the outbreak. Afflicted pigs have a high fever,

muscle stiffness, and labored breathing (thumps). Death losses are usually not high if good care if given the sick pigs, but losses in weight gains occur. Hogs raised in total confinement in which sanitation is good are not likely to contract the disease.

*Transmissible gastroenteritis (TGE)* is a virus-caused disease that is easily spread. Affected pigs show vomiting, diarrhea, and dehydration. Young pigs die. Because this disease spreads easily, almost all pigs in a herd will contract it once it starts. Death losses of 40% to 60% occur in pigs that are 3 weeks of age or younger. Older pigs may have the disease but in a much milder form. Within 48 hours after exposure to TGE, pigs start vomiting and scouring. The feces are green or yellowish green in color. The animals appear sleepy and droopy, the hair coat is ruffled, and weakness due to dehydration and weight loss occurs. Pigs that survive are severely stunted. Sows that contract TGE often show a marked reduction in milk production. No effective vaccine is known, so good sanitation, closed-herd production, and the isolation of young pigs from the general hog population are used on the farm to help prevent outbreaks.

Large hogs tend to develop immunity to TGE. Therefore, this disease usually does not occur in successive farrowings. Some producers expose sows to the disease when it is in the herd as a means of causing them to develop immunity. If this is done, it should be done prior to breeding or in early, rather than late, pregnancy.

*Tuberculosis* is a chronic disease. Swine are susceptible to the human, bovine, and avian types of tuberculosis. Animals can be intradermically tested. Intradermic, or "skin," testing is done by injecting killed tuberculosis-causing bacteria into the skin. Animals that have tuberculosis will react by developing a swelling in the skin at the site of the injection. Such reactor animals are eliminated. Because swine are susceptible to bovine tuberculosis, one should also consider testing cattle and eliminating affected individuals. Swine should never be housed with chickens, because swine are quite susceptible to avian tuberculosis.

# 24. Sheep Breeds and Breeding

Sheep have been bred in the past for three major purposes: the production of high yields of fine wool for making better clothing; the production of long wool for making heavy clothing, for making upholstering material, and for making rugs; and for the production of mutton and lamb. In more recent years, dual-purpose sheep breeds have been developed for producing wool and meat by crossing fine-wool breeds with long-wool breeds, after which selection has been practiced for improving both meat and wool production. Some miscellaneous breeds have been developed for specific purposes, such as the Navajo breed, which is used to produce wool for making Navajo rugs, and the Karakul breed, which is used to produce lambs for skinning to obtain pelts for such clothing items as caps.

## Characteristics of Breeds

The breeds of sheep are listed according to type (fine-wool, long-wool, meat, dual-purpose, and miscellaneous) in Table 24-1 with the production characteristics of each breed indicated. The breeds of sheep commonly used in the United States are shown in Figures 24-2 and 24-3. Fine-wool breeds of sheep and the dual-purpose breeds that possess fine-wool breeding have a herding instinct, staying in a group to graze as they move over a range. Therefore, one sheepherder with dogs can look after a band of 1,000 ewes and their lambs when they are on the summer range. Winter bands of 2,500 to 3,000 ewes are common. The meat breeds, by contrast, tend to scatter over the grazing area. They are high-

**Table 24-1. Characteristics of breeds of sheep within each type.**

| *Breed* | *Size* | *Mutton conformation* | *Wool fineness* | *Wool length* | *Fleece weight* | *Color* | *Horns or polled* | *Other* |
|---|---|---|---|---|---|---|---|---|
| | | | | Fine-wool breeds | | | | |
| Merino | Small to medium | Poor | Very fine | Medium | Heavy | White | Rams horned, ewes polled | Good herding instinct |
| Rambouillet | Large | Medium | Fine | Medium | Heavy | White | Rams horned, ewes polled | Good herding instinct |
| Debouillet | Medium | Poor | Fine | Medium | Heavy | White | Rams horned, ewes polled | Good herding instinct |
| | | | | Long-wool breeds | | | | |
| Romney | Medium large | Medium to good | Coarse | Long | Heavy | White | Polled | Spread in lambing date, lambs don't fatten well |
| Lincoln | Large | Good | Coarse | Long | Heavy | White | Polled | Lambs don't fatten at small size |
| Leicester | Large | Good | Coarse | Long | Heavy | White | Polled | Lambs don't fatten at small size |
| Cotswold | Large | Good | Coarse | Long | Heavy | White | Polled | Lambs don't fatten at small size |
| | | | | Mutton breeds | | | | |
| Suffolk | Large | Excellent | Medium | Very short | Very light | White with black bare face and legs | Polled | Bare bellies, good milkers, black fibers |
| Hampshire | Large | Excellent | Medium | Medium | Medium | White with black face | Polled | Wool blindness, good milkers, black fibers |
| Shropshire | Medium to large | Good | Medium | Medium | Medium | White, dark face and legs | Polled | Wool blindness, excellent milkers |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Southdown | Very small | Excellent | Medium | Short | Very light | White with brown face and legs | Polled | Used in hot house lamb production |
| Dorset | Medium | Good | Medium | Medium | Medium | White | Horned rams and ewes | Highly fertile, good milkers |
| Cheviot | Small | Excellent | Medium | Medium | Medium | White | Polled | Very rugged |
| Oxford | Large | Excellent | Medium | Medium | Medium to heavy | White, brown face and legs | Polled | |
| Tunis | Medium | Medium | Medium | Medium | Medium | Red or tan face | Polled or horned | |
| Dual-purpose breeds | | | | | | | | |
| Corriedale | Medium to large | Good | Medium | Medium long | Heavy | White | Polled | Herding instinct |
| Columbia | Large | Good | Medium | Medium long | Heavy | White | Polled | Rugged, herding instinct |
| Targhee | Medium to large | Medium to good | Medium to fine | Medium | Heavy | White | Polled | Herding instinct |
| Panama | Large | Good | Medium | Medium long | Heavy | White | Polled | |
| Romeldale | Medium to large | Good | Medium | Medium | Heavy | White | Polled | |
| Montadale | Medium to large | Good | Medium | Medium | Medium | White | Polled | |
| Miscellaneous breeds | | | | | | | | |
| Navajo | Medium | Poor | Coarse | Long | Medium | Variable | Polled or horned | Wool for making Navajo rugs |
| Karakul | Large | Poor | Coarse | Long | Medium | Black or brown | Rams horned, ewes polled | Used for pelts |

**FIGURE 24-1.** *Sheep provide meat and/or milk for human consumption in many parts of the world as well as wool for making clothing. Sheep have declined greatly in numbers in the United States in the past 40 years. Much of the decline has been in range sheep because of the difficulty in obtaining good herders. Farm-flock sheep occupy an important position because they can digest feed sources that are otherwise wasted. Sheep producers must increase rate and efficiency of production if they are to compete with producers of swine and beef cattle. Courtesy of Office of Communication USDA, photo IDA-45252, USDA-SCS photograph by Frank Roadman.*

ly adaptable to grazing fenced pastures where feed is abundant. Meat-type rams are often used for breeding ewes of fine-wool breeding on the range for the production of market lambs.

The Columbia and Targhee breeds were developed by the U.S. Sheep Breeding Laboratory, Dubois, Idaho. Both breeds have proven useful on western ranges because they have the herding instinct and they raise better market lambs when bred to a meat breed of ram than do the fine-wool ewes. The U.S. Sheep Breeding Laboratory has made great strides in improving the Rambouillet, Columbia, and Targhee breeds of sheep. These three breeds were faulted by having body folds or wrinkles which made shearing extremely difficult, and by "wool blindness" (a situation in which wool covering the face prevents the sheep from seeing). Wool blindness prevented the sheep from observing dangers and interfered with their ability to locate forage. Thus, wool-blind ewes weaned lambs that averaged about 11 lbs. less than those produced by open-faced ewes.

Selection against wool blindness and body folds had to be done by use of a subjective score because there was no way to accurately measure these traits. After several years of selection, the average score for these two undesirable traits was approximately the same as the average initial score prior to the selection program. However, photographs showed clearly that rapid progress was being made. Those persons doing the scoring were comparing sheep born within the same year and, as the traits were improved, the requirements for a particular score increased from one year to the next.

The most important trait in meat breeds of sheep is weight at 90 days (3 months) of age, with some emphasis also given to conformation and finish of the lambs. Weight at 90 days of age can be calculated for the crosses in which lambs are weaned at younger or older ages than 90 days as follows:

$$\text{90-day weight} = \frac{\text{Weaning weight - birth weight}}{\text{Age at weaning}} \times 90 + \text{Birth weight}$$

Dorset

Montadale

Polled Dorset

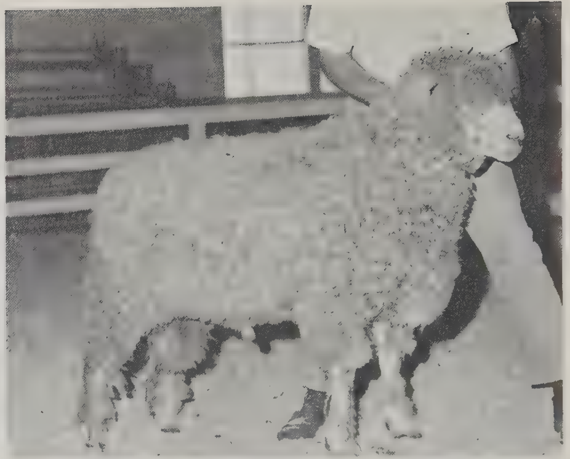
Cheviot

Hampshire

Suffolk

**FIGURE 24-2.** *Some breeds of sheep commonly used either as straightbreds or for crossbreeding to produce market lambs. Courtesy of Continental Dorset Club, Hudson, Iowa (Dorset and Polled Dorset), Montadale Sheep Breeders' Association, Indianapolis, Indiana (Montadale), American Cheviot Sheep Society, Carlisle, Iowa (Cheviot), the John and Mike Caskey families (Hampshire), and National Suffolk Sheep Association, Columbia, Missouri (Suffolk).*

Rambouillet



Cotswold


Lincoln

Romney

Targhee

Finnsheep

**FIGURE 24-3.** *Some breeds of sheep commonly used either as straighbreds or for crossbreeding to produce market lambs. Courtesy of American Rambouillet Sheep Breeders Association, San Angelo, Texas (Rambouillet), American Cotswold Record Association, Fremont, Ohio (Cotswold), National Lincoln Sheep Breeders' Association, West Milton, Ohio (Lincoln), American Romney Breeders Association, Corvallis, Oregon (Romney), USDA, ARS, Western Region, U.S. Sheep Experiment Station, Dubois, Idaho (Targhee), and Animal Science Department, University of Minnesota (Finnsheep).*

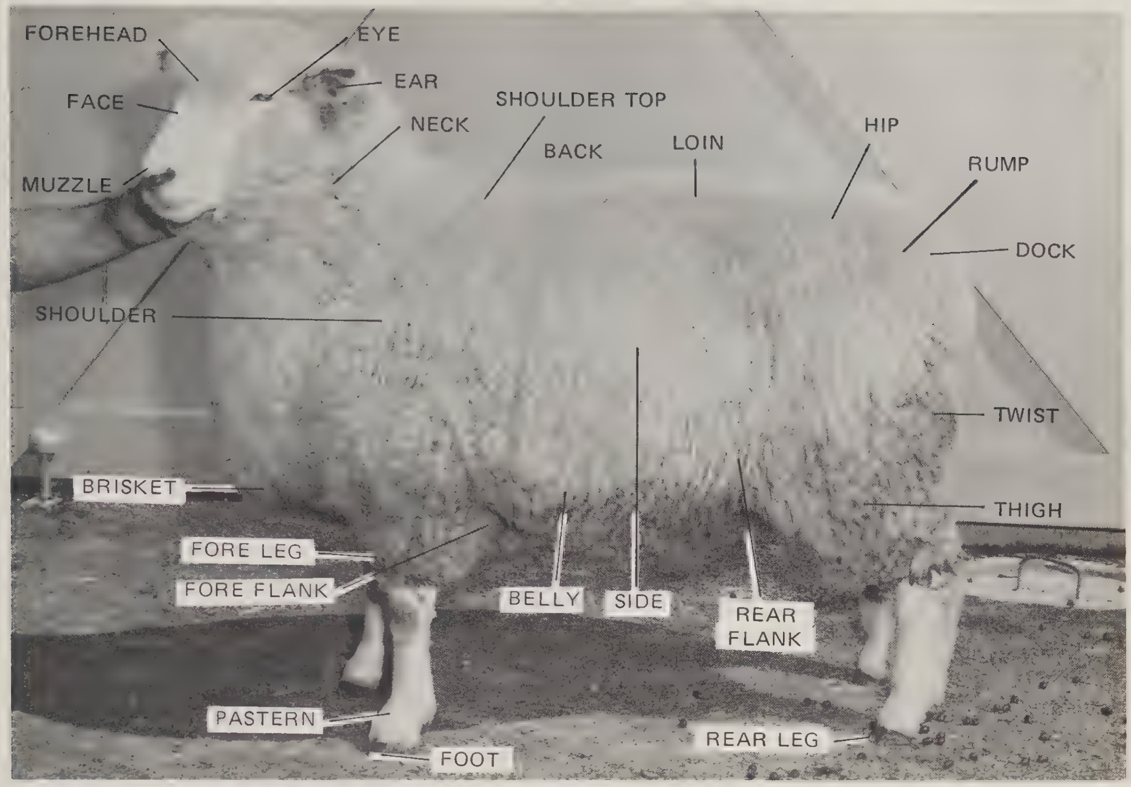



**FIGURE 24-4.** *The external parts of the sheep. Courtesy of Dr. John Landers, Animal Science Department, Oregon State University.*

If a lamb weighs 10 lbs. at birth and 100 lbs. at 100 days, the 90-day weight is:

$$\frac{100 - 10}{100} = .9 \times 90 = 81 + 10 = 91 \text{ lbs.}$$

If the birth weight was not recorded, one can use a figure of 8 lbs. for birth weight.

Approximately 85% to 90% of the total income from sheep of the meat breeds is derived from the sale of lambs, with only 10% to 15% coming from the sale of wool. The sheep that are used in the production of fine or long wool show a larger percentage of income from them being derived from the sale of wool (about 30% to 35%) than is obtained from meat breeds. Even with these breeds, the income from lambs produced constitutes the greater portion of total income.

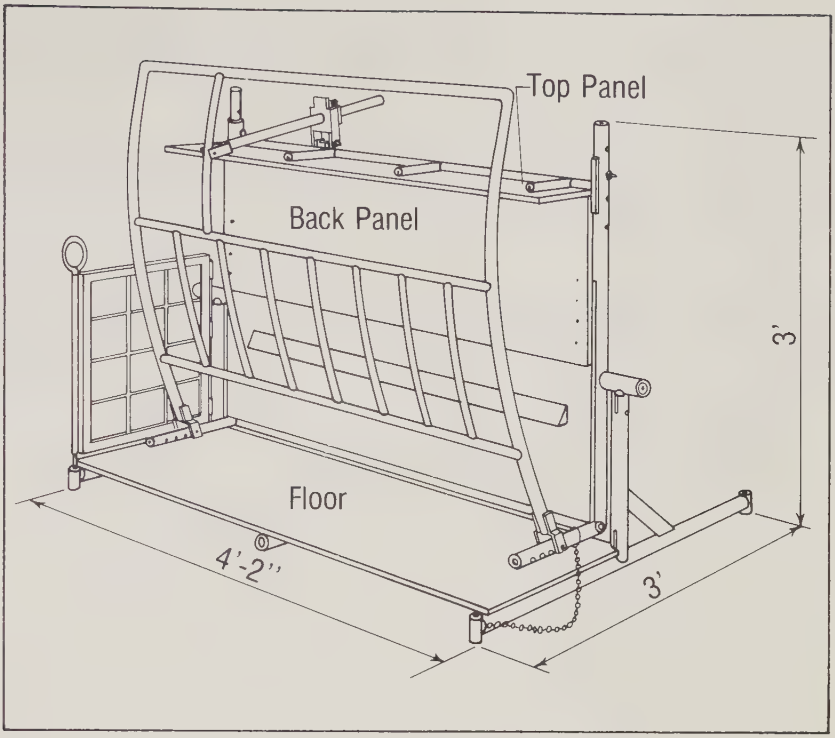
## Controlling Diseases and Parasites

Sheep raised by most producers are confronted with a few serious diseases, several serious internal parasites, and some external parasites. Some common diseases of sheep are the following:

*Enterotoxemia* ("overeating disease") is most often serious when sheep are in a high nutritional state (for example, lambs in the feedlot), but it can affect sheep that are on lush pastures. The disease can be prevented by administering Type D toxoid. Usually, three treatments are given; two about 4 weeks apart and a booster treatment 6 months later. Losses from this disease among young lambs can be prevented by vaccinating pregnant ewes.

*Entropion,* or turned-in eyelids, is under genetic control and should be selected against. The irritation to the eye results in infections to the eye and may lead to blindness if corrective measures are not taken. One

FIGURE 25-5. *A tilting squeeze chute for restraining sheep. Courtesy of Mr. John H. Pedersen, Midwest Plan Service, Agricultural Engineering, Iowa State University, Ames, Iowa.*




can remove a small strip of skin from above the upper eyelid and from below the lower eyelid with small, sharp scissors. The scar tissue pulls the eyelids so they do not turn in. One may also suture through the eyelids and tie the upper lid to skin above the eye and the lower lid to skin below the eye.

*Footrot* is one of the most serious diseases of the sheep industry because of its common occurrence. The disease cannot be treated with systemic medication because rotting of the tissue between the horny part of the hoof and the soft tissue below occurs. It can be cured by severe trimming so that all affected parts are exposed, treating the diseased area with 10% formaldehyde (1 part of 38% formalin to 19 parts of water), and then turning the sheep into a clean pasture so that it does not become reinfected. A tilting squeeze is useful for restraining sheep that need treatment (Figure 25-5). One must use formaldehyde with caution because the fumes are damaging to the respiratory system.

Once all sheep in the flock are free of footrot, it can best be prevented by making sure that it is not introduced into the flock again. Rams introduced for breeding should be isolated for 30 to 60 days to allow an opportunity for footrot to show. No animal showing evidence of footrot should come into the flock. At present, much research is being conducted in an attempt to develop a vaccine against footrot. Some promising results indicate that the disease may be brought under control by this method.

*Pneumonia* usually occurs when animals have been stressed by other diseases, parasites, improper nutrition, or exposure to severe weather conditions. When pneumonia is recognized early, sulfonamides and antibiotics are usually effective against it. The afflicted animal should be given special care and kept warm and dry.

*Ram epididymitis* is an infection of the epididymis which reduces fertility. It can be controlled by vaccinating all rams 1 month before the breeding season. This should be done each year even if a ram was vaccinated the previous year.

*Sore mouth* usually affects lambs. It can be contracted by humans. It is caused by a virus. It can be controlled by vaccination, but one should not vaccinate if this disease is not on the premises because this will introduce it.

Sheep are subject to a nutritional disease known as *white muscle disease.* To prevent it, one should give pregnant ewes an injection of selenium during the last one-third of pregnancy and give lambs an injection of selenium at birth.

Sheep have internal and external parasites. The interal parasites are by far the more serious.

*Liver flukes* that infest sheep have snails as the intermediate host. After the infective stage of the fluke leaves the snail, it stays in water that sheep may drink, or, more frequently, encysts on grass that sheep may eat. One should either drain or treat wet areas with copper sulfate to destroy snails. Sheep should not be provided water in ponds because snails are most likely to be present in such an area. Water can be piped from a fenced pond so that clean water is provided. Afflicted sheep can be treated with an antihelmintic, such as carbon tetrachloride. Great caution is needed in treating with carbon tetrachloride, because it is a dangerous drug that can kill the sheep.

*Stomach worms* constitute one of the most serious problems to sheep producers. Stomach worms develop resistance to the vermifuge used; consequently, one must switch vermifuges. For example, one may drench sheep prior to sending them to pasture with micromized (fine-particle) Phenothiazine, after which one treats the sheep with mixtures of 1 part of Phenothiazine to 9 parts of salt to hold down infestation in the summer. At the end of the pasture season, the sheep may be drenched with Tramisol. Sheep raised in drylot (lots in which the only feed available is that which the operator supplies) are not likely to become infested with stomach worms. Some recent research in Idaho indicates that raising farm-flock sheep in drylot may be as economical as pasturing them on highly productive land.

*Nodular worms* cause knots, or nodules, in the cecum and colon of sheep. Treatments for control of stomach worms are also effective in controlling nodular worms.

External parasites that are common with sheep include blowfly maggots, keds (sheep ticks), lice, mites, screw-worms, and sheep bots.

In wet periods when the weather is warm, blowflies may lay hundreds of eggs that hatch into *maggots* which irritate the skin of sheep. One should shear the area of the body where maggots are located and treat with Co-Ral or Ronnel, either by rubbing or spraying the affected immediate areas with the treatment substance used.

*Keds* (sheep ticks) are bloodsucking parasites. Sheep may be dipped, dusted, or sprayed, using such insecticides as Malathion, Ronnel, Toxaphene, or Diazinon. If sheep are sprayed, the spray should be applied under high pressure (400 lbs.) to insure that the spray penetrates the wool.

*Lice* cause irritation to sheep and damage to wool. They are more

likely to be serious when they infest sheep that are unthrifty. They are controlled by dipping, dusting, or spraying, as is done to control sheep ticks.

*Mites* spread mange, and they themselves are spread from sheep to sheep. One should be certain that any sheep introduced into the flock do not have mange. Mites are controlled by dusting or spraying with lime sulfur or Toxaphene.

All parasites that can be controlled by dipping, dusting, or spraying with an effective insecticide are controlled only if a systematic treatment schedule is followed. The insecticide kills only the adults and does not destroy the eggs of these parasites; consequently, two applications of the insecticide are necessary. The timing of the second application of insecticide is determined by the life cycle of the parasite. In order for the second dusting, spraying, or dipping to be effective, the eggs of the parasite should have hatched but the adults should not, have had time to lay more eggs. Guidance on timing of applications of insecticides can be obtained from an extension service or a veterinarian.

*Screw-worms* can attack any wound. Any wound such as one caused by castration or docking or by predatory animals should be protected by use of a fly repellant. Infested areas can be treated with Ronnel or Co-Ral to destroy the screw-worm maggots.

*Sheep bot,* or "grub in the head," results from a nasal fly that deposits larvae on the nostrils of sheep. These larvae crawl up the nasal passages and locate in the frontal sinuses. Drenching with Ruelene is recommended.

Range sheep that are moved over vast areas while grazing are less likely to reinfest themselves by contacting voided parasite eggs than are sheep that graze over the same area for protracted periods of time.

The same general health program and treatments for diseases and parasites that have been discussed for farm-flock sheep are applicable for range sheep. It is possible that range sheep are more subject to nutritional deficiencies than are sheep of farm flocks. They can also be stressed more because of hauling or trailing. They can also come in contact with more poisonous plants than farm-flock sheep. The herder who is attending 1,000 or more sheep on the range has grave responsibilities. The herder can do much to keep them from areas where poisonous weeds abound and where there are predators. The herder can also do a great deal to see that the sheep are on good range at all times. If the herder accomplishes these things, the incidence of diseases and parasites should be minor. Once a sheep on the range becomes very ill from a disease, death results because it is impossible to provide the individual attention necessary to assist it to recover.

# 26. The Poultry Industry

Poultry and mankind have long been associated. The chicken, for example, was domesticated by 2000 B.C. It was probably domesticated earlier. The poultry industry of the United States is based mostly on fowl that came from elsewhere. The turkey is the only species of poultry known to have originated in America. Its natural range was centered in Mexico and what is now the southwestern United States, where pioneers found it abundant. Columbus brought chickens, ducks, and geese on his second voyage to America in 1493, the first introduction of these fowl into America on record.

## Origin and Domestication of the Chicken

It was thought by Charles Darwin (the 19th-century biologist who proposed the modern theory of evolution) and others that the chicken originated from the wild jungle fowl of Southeast Asia. Some characteristics of wild fowl still found there are apparent in many of our present-day domesticated fowl.

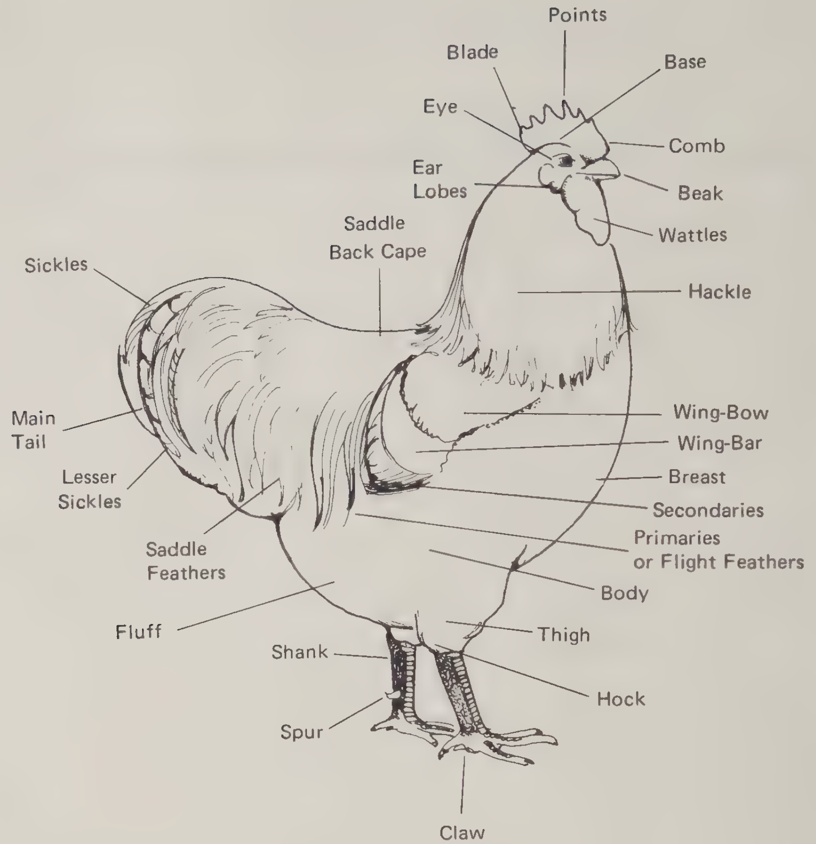
The use of poultry meat and eggs as human food probably dates back to early civilization. Artificial incubation of chicken eggs was known in Biblical times. Huge clay ovens, designed to hatch large numbers of eggs, were used in China as early as 246 B.C. to 207 B.C. (Landauer, 1951).

The sport of cockfighting probably contributed greatly to the spread of the chicken from the Far East to the Middle East and on to the Near



This chapter was written by Dr. Daniel C. Hutto specially for this book.

FIGURE 26-1. *The external parts of the chicken. Redrawn from USDA.*




East. Chickens were in the caravans of nomadic tribes that moved back and forth across the deserts of the Middle East. Each tribe probably used some of its birds as a source of food and kept others for cockfighting with birds of other tribes. This life style is still prevalent, to a lesser degree, in the Middle East—particularly in the Afghanistan-Pakistan-Iran area.

Evolutionary forces and domestication played major roles in changing the prehistoric fowl into the jungle fowl, and the jungle fowl into our modern fowl. Selection, natural and practiced, has also contributed much to the changes that have taken place in fowl through time. The external parts of the chicken are shown in Figure 26-1.

## Characteristics of Breeds

The term *poultry* applies to chickens, turkeys, geese, ducks, pigeons, peafowls, guineas, and game birds.

**Chickens.** Chickens are classified according to class, breed, and variety. A *class* is a group of birds that has been developed in the same geographical area. The four classes of chickens are: American, Asiatic, English, and Mediterranean. A *breed* is a subdivision of a class composed of birds of similar size and shape. Some important breeds of chickens are listed in Table 26-1; some are shown in Figure 26-2. A *variety* is a subdivision of a breed composed of birds of the same color and type of comb (Figure 26-3).

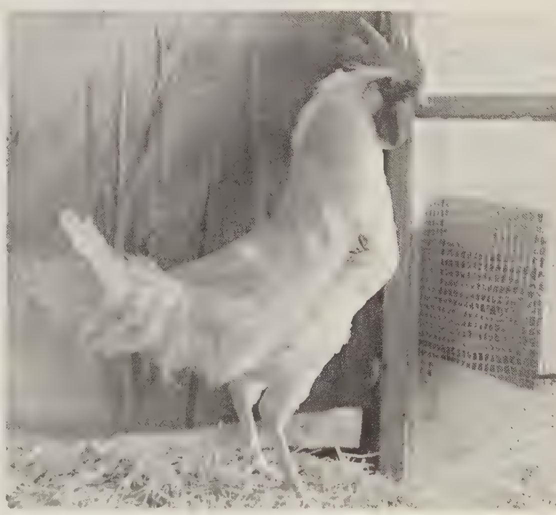
White Plymouth Rock

S. C. White Leghorn (exhibition type)

White Cornish

New Hampshire Red

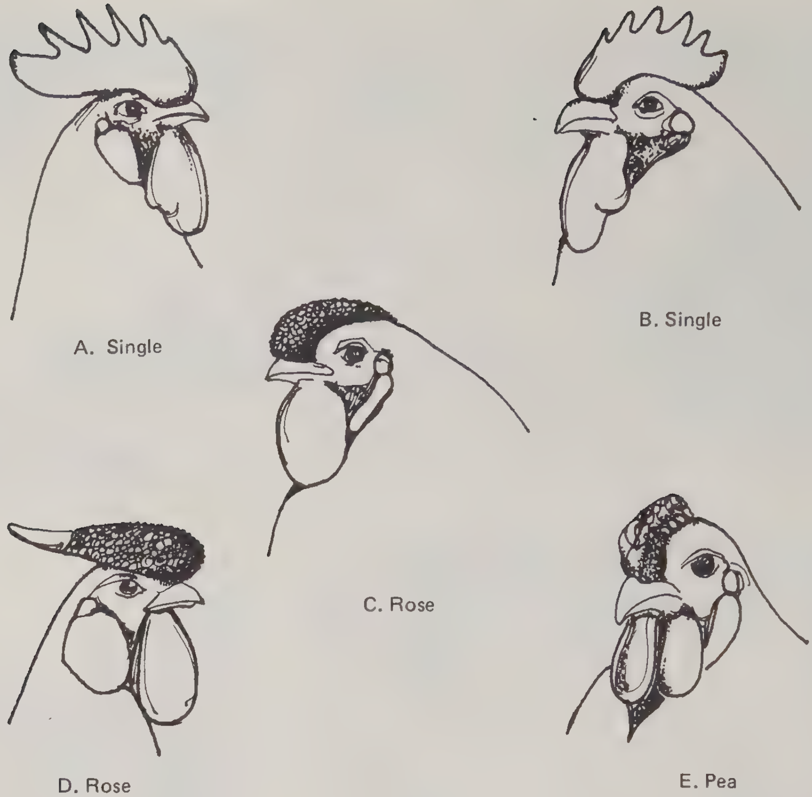
Barred Plymouth Rock



Hybrid Leghorn

FIGURE 26-2. *Some breeds of chickens. Courtesy of Halbach Poultry Farm, Waterford, Wisconsin.*

FIGURE 26-3. *Types of combs of chickens. Redrawn from USDA.*




In the past several decades, the popularity of many breeds has declined steadily. This trend has been dictated by the industry itself in that only the breeds that possess the characteristics most preferred by the industry have increased in numbers. Factors such as egg numbers, eggshell color, egg size, efficiency of production and fertility, and hatchability are most important to commercial egg producers. Broiler producers consider such characteristics as plumage color, egg production, fertility, hatchability, growth, feed efficiency, livability, "picking quality," and grade. Also, breeds that cross well with each other are important to broiler breeders.

**Table 26-1. Certain breeds of chickens and their main characteristics.**

| *Breed* | *Purpose* | *Type of comb* | *Color of egg* |
|---|---|---|---|
| American breeds | | | |
| White Plymouth Rock | Eggs and meat | Single | Brown |
| Wyandotte | Eggs | Rose | Brown |
| Rhode Island Red | Eggs | Single and Rose | Brown |
| New Hampshire | Eggs and meat | Single | Brown |
| Asiatic breeds | | | |
| Brahma (light) | Meat | Pea | Brown |
| Cochin | Meat | Single | Brown |
| English breeds | | | |
| Australorp | Eggs | Single | Brown |
| Cornish (white) | Meat | Pea | Brown |
| Orpington | Meat | Single | Brown |
| Mediterranean breed | | | |
| White Leghorn | Eggs | Single and Rose | White |

FIGURE 26-4. *Ideal Broad Breasted Bronze turkeys, male, or tom (left), and female. Courtesy of Nicholas Turkey Breeding Farms, Sonoma, California.*

The breeds of chickens listed in Table 26-1 were developed many years ago. They are still used, to a certain degree, in poultry breeding. Some breeds are more a novelty than a part of the mainstream of the industry. Many of these are propagated for specialty markets where such characteristics as plumage color, comb type, and eggshell color might be considered important.

**Ducks.** Many breeds of domestic ducks are known but only a few are of economic importance. Most of the important breeds combine good egg production with excellent meat qualities. The most popular breeds for commercial production are: White Pekin, Muscovy, Rouen, Khaki Campbell, and Indian Runner. The Pekin is the most popular because of its high quality of meat and egg production. The Pekin produces excellent carcasses in a rather short time—7 to 8 weeks of age. The Khaki and Indian Runner are noted for egg production. The Muscovy (white) and Rouen possess excellent market characteristics. Regardless of the breed, one should choose ducks that are hardy, that have good ranging ability, and that have good dressing and market qualities.

**Geese.** Several breeds of geese are rather popular with most commercial producers. The Embden, Toulouse, White Chinese, and Pilgrim are rather satisfactory for meat production. Birds of medium body size are preferred by a majority of commercial producers. According to Orr (1974), the characteristics that are desirable in geese are: medium-sized carcass, good livability, rapid growth, and heavy coat of white or nearly white feathers. The Embden is a nearly white breed that meets the above requirements. The Toulouse is gray. The Pilgrim is white. The White Chinese male is white and the female is light gray.

The value of feathers should also be considered in duck and geese production. Because feathers of these species are used by the clothing industry, properly processed feathers can provide income.

**Turkeys.** The turkey was domesticated in America and was later introduced elsewhere. In the late 1400's, turkeys were taken to Spain by Spanish traders.

Several varieties of turkeys are important today: Broad Breasted Bronze (Figure 26-4), Beltsville White (small bird), and White Hol-

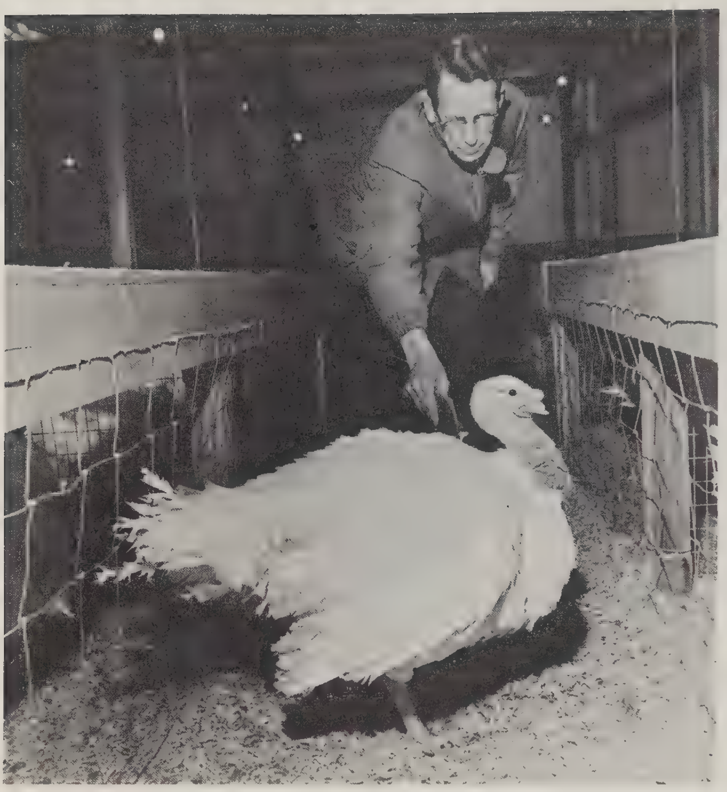


FIGURE 26-5. *Ideal Broad Breasted White turkey, male. Courtesy of Nicholas Turkey Breeding Farms, Sonoma, California.*

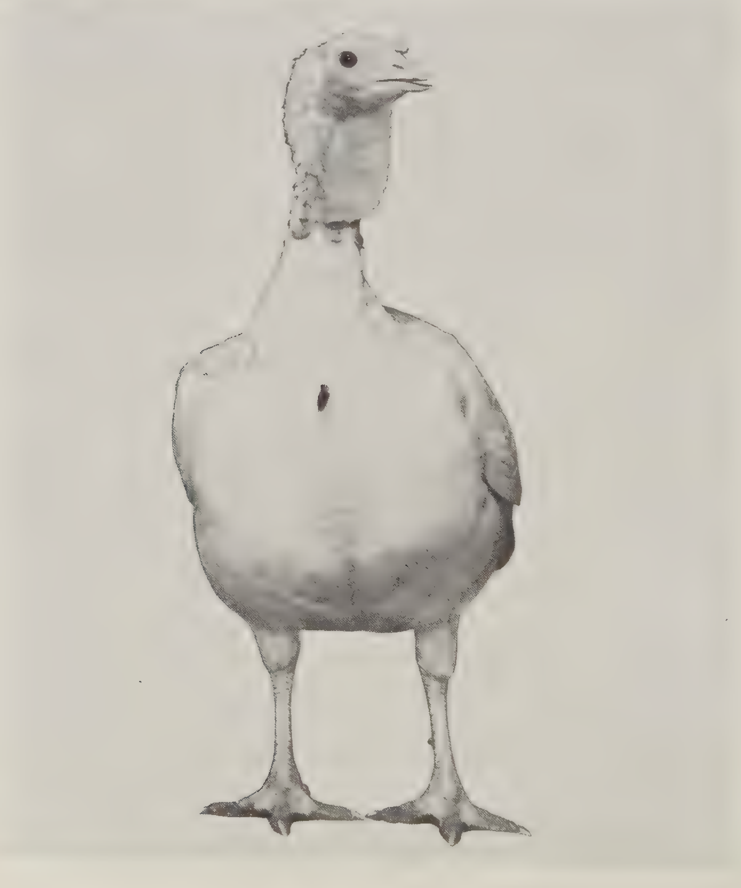


FIGURE 26-6. *Ideal Broad Breasted White turkey, female. Courtesy of Nicholas Turkey Breeding Farms, Sonoma, California.*

land. Since the 1950's, the emphasis has been to produce more large white turkeys (Figures 26-5 and 26-6). A corresponding decrease in the number of Broad Breasted Bronze and small whites has occurred. The large whites that are found in great numbers today were originally produced by crossing the Bronze with the White Holland. The first-generation offspring of this cross were mated and the resulting second-generation white females were backcrossed to Bronze males. This mating scheme was repeated for several generations until the offspring showed a high degree of similarity to the Broad Breasted Bronze in size and structure, and showed the white plumage of the White Holland. White plumage is so important to today's commercial producers because birds that possess it are favored by dressing plants for their "picking" qualities.

The large varieties are preferred by such consumers as large families, restaurants, and the military establishment. The Beltsville White is a smaller variety than the Broad Breasted varieties. It appeals to smaller families and groups that desire a carcass of 8 to 12 lbs. The Beltsville White also produces a large number of eggs.

The day-old turkey poult is much more expensive than the day-old chicken, primarily because fertility, egg production, and hatchability of eggs are relatively low in most varieties of turkeys. The average turkey lays slightly fewer than 100 eggs yearly. About 50% to 65% of these eggs hatch.

# 28. Important Characteristics of Horses and Donkeys

Horses and donkeys and their crosses, mules and hinnies, have contributed greatly to civilization. The mule is produced by crossing the male donkey (jack) and the female horse (mare). The hinny is produced by crossing the male horse (stallion) and the female donkey (jenny). In the past, all of these animals provided a swifter method for humans to move long distances than was possible on foot. Also, heavier loads could be moved either by pack animals or by animals pulling loads than was possible by hand. Thus, communication and transportation were enhanced by use of horses, donkeys, mules, and hinnies. These animals had a large role in providing power for farming, logging, mining, and transporting materials of all types.

Horses and mules provided a means of transporting grains and livestock to centers where they could be marketed or moved further by other means. The railroad and early road beds were developed by use of horses and mules as the source of power for moving dirt, ties, and rails. The peak of using horses and mules was reached during World War I. These animals played a big part in the war.

The need for a power source such as the combusting of petroleum products was stimulated by the war. During the war and following it, tractors, trucks, and automobiles were produced in large quantities. These mechanical devices made it possible to move heavier loads at higher speeds, to farm larger acreages with less personnel, and to transport people at much greater speeds than is possible with horses and mules. As a result, the need for draft horses and mules declined rapidly. The number of horses in the United States declined from a high of 18

million in 1920 to a low of 3 million in 1940. In the past 35 to 40 years, the number of pleasure horses has increased at a rapid rate, because people have more leisure time. The use of horses provides a desirable way to spend leisure time. Some horses are presently used in handling livestock and in certain logging operations. Many horses are used for pleasure riding by people of all ages. Some horses are used in parades where the appearance of the animals is important. Horses are essential in sports such as racing, rodeos, and polo.

Several terms are used by persons working with horses. A *stallion* is an intact male horse of breeding age. A *gelding* is a male horse that was castrated prior to reaching sexual maturity. The young female is called a *filly.* The young male is called a *colt.* Fillies and colts are collectively called *foals.* A female of breeding age is a *mare.* Horses are sold under such terms as "at the halter," which means that no guarantee exists that the horse is sound or usable; "sound," which means the horse has no unsoundness but may be mean or unbroken, or "fully guaranteed," which means the horse is sound and is well trained.

Horses have been used for so many special purposes that many breeds have been developed as a means of supplying the proper horse for a particular need. The major breeds of horses and the primary use each serves are listed in Table 28-1. It should be kept in mind that horses of most breeds may be used for several purposes. No attempt is made in Table 28-1 to indicate all the ways each of the breeds are used. For example, the Thoroughbred (Figures 28-1 and 28-2) is classified as a racehorse primarily for long races, but it is used for several other functions.

## Important Characteristics of Horses

The usefulness of a horse depends on how well the horse responds to the commands of its rider; therefore, temperament is of the utmost importance. Also, horses are used primarily for pleasure, and the beauty of a horse contributes to the pleasure of owning and using it. Thus, color and color markings are important in pleasure horses. Horses that are used for pleasure riding, roping, jumping, or racing must have correct conformation to assure ease of riding; they must have the ability to endure the stresses to which they are put; and they should be sure-footed. All horses should have normal respiration, particularly in situations where horses are to be stressed, as in racing. The vision of the horse is important to both the horse and its user.

Two terms are used in denoting abnormal conditions in horses; unsoundness and blemish. An *unsoundness* is any defect that interferes with the usefulness of the horse. It may be caused by an injury or improper feeding, it may be inherited as such, or it may develop as a result of inherited abnormalities in conformation. A *blemish* is a defect that detracts from the appearance of the horse but does not interfere with its usefulness. A wire cut or saddle sore may cause a blemish without interfering with the usefulness of the horse.

## Abnormalities of Horses

A knowledge of the parts of the horse is important to the understanding of abnormal conditions. The external parts of the horse are shown in Figure 28-3.

**Table 28-1. Characteristics and uses of the breeds of horses.**

| *Breed* | *Color* | *Height in hands*[a] | *Weight in lbs.* | *Uses* |
|---|---|---|---|---|
| | | Riding and harness horses | | |
| Arabian | Bay, chestnut, brown, gray | 14.2 to 15.2 | 850 to 1,000 | Pleasure |
| Thoroughbred | Bay, brown, gray, chestnut, black, roan | 15.2 to 17.0 | 1,000 to 1,300 | Long races |
| Morgan | Bay, chestnut, brown, black | 14.2 to 15.2 | 950 to 1,150 | Pleasure |
| Standardbred | Bay, chestnut, roan, brown, black, gray | 14.2 to 16.2 | 850 to 1,200 | Harness racing |
| American Saddle Horse | Chestnut, bay, brown, black | 15.0 to 15.3 | 1,000 to 1,150 | Gaited, saddle, show |
| Tennessee Walking Horse | All colors | 15.0 to 16.0 | 1,000 to 1,200 | Riding for pleasure |
| Hackney | Bay, chestnut, black, brown | 15.0 to 16.0 | — | Heavy harness |
| American Quarter Horse | All colors | 14.2 to 15.2 | 1,000 to 1,250 | Short races, stock horses |
| | | Ponies | | |
| Pony of America | Appaloosa | — | — | Riding by children |
| Hackney | Bay, chestnut, black, brown | 11.2 to 14.2 | 450 to 850 | Harness pony |
| Welsh | Bay, chestnut, black, roan, gray | 11.0 to 13.0 | 350 to 500 | Riding by children |
| Shetland | Bay, chestnut, brown, black, mouse, spotted | 9.2 to 10.0 | 300 to 400 | Riding by children |
| | | Draft | | |
| Percheron | Black, gray usually | 15.2 to 17.0 | 1,600 to 2,200 | Heavy pulling |
| Clydesdale | Bay, brown, black | 15.2 to 17.0 | 1,700 to 2,000 | Heavy pulling |
| Shire | Bay, brown, black | 16.2 to 17.0 | 1,800 to 2,200 | Heavy pulling |
| Belgian | Chestnut, roan usually | 15.2 to 17.0 | 1,900 to 2,400 | Heavy pulling |
| Suffolk | Chestnut | 15.2 to 16.2 | 1,500 to 1,900 | Heavy pulling |
| | | Color registries | | |
| Palomino | Palomino | Any height | | Parade use |
| Appaloosa | Tiger, blanket | Any height | | Parade use |
| Paint | Tobiano, overo | Any height | | Parade use |

[a]Height is measured in inches but reported in "hands." A "hand" is 4 inches.

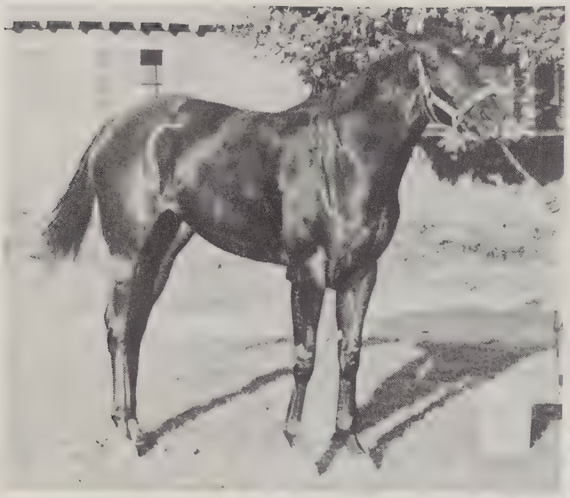


FIGURE 28-1. *Ruffian, a great Thoroughbred filly. Note the beautiful conformation with strong muscling. Horses of this high stage of perfection are the result of planned breeding, proper feeding, and good care. Horses are used primarily as pleasure or recreational animals. Such activities as racing, rodeos, packing, and pleasure riding are included in pleasure or recreation. In addition, horses are used in the handling of livestock on farms and ranches. The Thoroughbred has been bred for many years as a racehorse. Thoroughbreds are excelled as racehorses particularly in the races of long distances. Courtesy of New York Racing Association and Mr. Louis Weintraub, Photo Communications Co., and the Jockey Club, New York, New York.*

FIGURE 28-2. *The Thoroughbred, Foolish Pleasure, in action. Note the extreme muscular development that gives the horse great speed. Thoroughbreds are great long-distance racehorses. Courtesy of New York Racing Association and Mr. Louis Weintraub, Photo Communications Co., and the Jockey Club, New York, New York.*

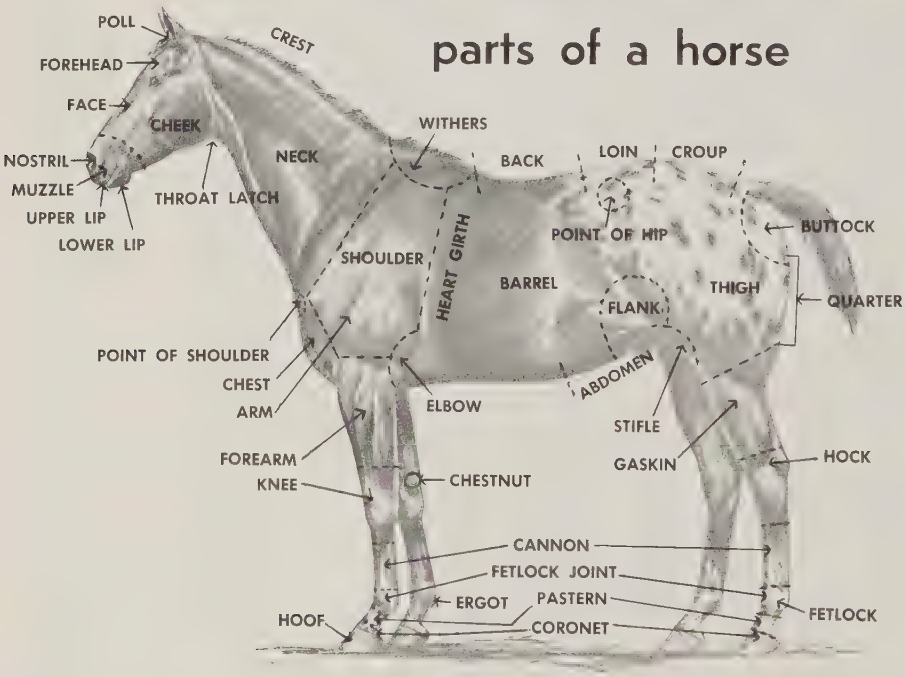



FIGURE 28-3. *The external parts of the horse. Courtesy of Appaloosa Horse Club, Moscow, Idaho.*

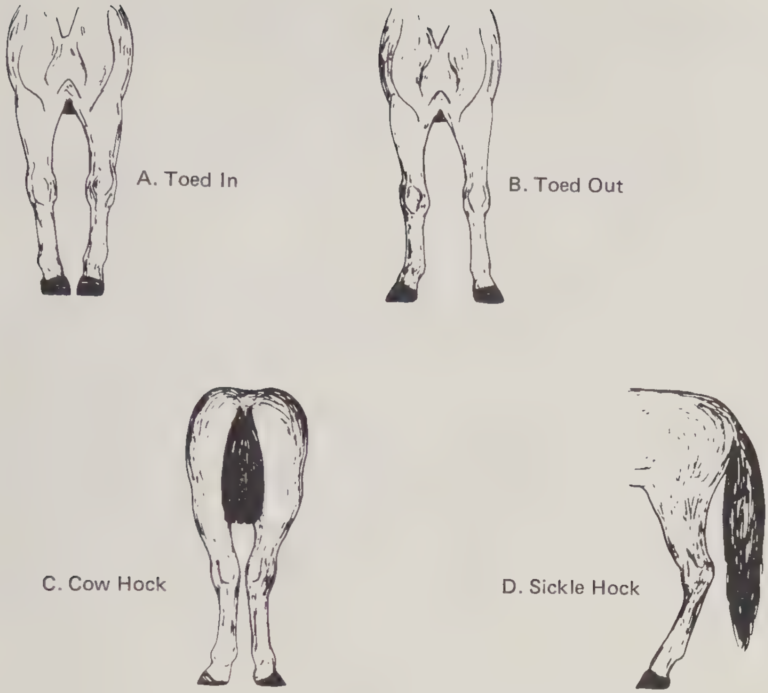



FIGURE 28-4. *Drawings illustrating toeing in, toeing out, cow hocks, and sickle hocks of horses. All four of these abnormalities affect the way horses travel and they may lead to the development of unsoundnesses.*

Horses may have anatomical abnormalities which interfere with their usefulness. Many of these abnormalities are either inherited directly or develop because of an inherited condition. There are abnormalities of the eyes, respiratory system, circulatory system, and of the conformation of the feet and legs.

*Cataract* is inherited as a dominant trait that could be eliminated if it were not that horses produce several foals before the cataract develops.

*Moon blindness* is periodic *ophthalmia* in which the horse is blind for a short time, regains its sight, and then again becomes blind for a time. Periods of blindness may initially be spaced as much as 6 months apart. The periods of blindness become progressively closer together until the horse is continuously blind. This condition received the name "moon blindness" because the trait is first noticed as a reality when the periods of blindness occur about a month apart. It was originally thought that the periods of blindness were associated with changes in the moon.

*Heaves* is a respiratory defect in which the horse experiences difficulty in exhaling air. The horse can exhale a certain volume of air normally, after which an effort is exerted to complete exhalation. This condition is extremely serious when horses are placed under the stress of exercise.

*Ruptured blood vessels* is a defect of circulation in which the blood vessels are fragile and may rupture when the horse is put under the stress of exercising. Some racehorses have been lost due to hemorrhage from these fragile blood vessels.

*Toeing in* (Figure 28-4A) refers to the turning in of the toes of the front feet, whereas *toeing out* (Figure 28-4B) refers to the turning out of the toes of the front feet. These conditions influence the way in which the horse will move its feet when it travels.

The term *cow hocks* (Figure 28-4C) indicates that the hocks are close together but the hind feet are far apart. Such hocks are greatly stressed when the horse is pulling, running, or jumping.

*Sickle hocks* (Figure 28-4D) is a term used when the hock has too much set or bend. As a result, the hind feet are too far forward. The strain of pulling, jumping, or running is much more severe on a horse with sickle hocks than on a horse whose hocks are of normal conformation.

*Contracted heels* is inherited, with two dominant genes acting complementarily to produce the trait. Thus, genes *A* or *C* alone do not cause the trait to develop; it is expressed only when both genes *A* and *C* are present. Because of this mode of inheritance, horses that have contracted heels may produce offspring that do or do not have contracted heels. Also, horses that have normal heels can produce some offspring that have contracted heels. The foot of the horse is constructed with cartilage between the bone of the foot and the horny hoof. The heel can be spread apart because the cartilage of the heel bends. This provides a shock-absorbing mechanism for the foot. When the heel is contracted, it cannot spread; therefore, the pounding of the foot bruises the cartilage and it heals by ossification.

*Sidebones* is the abnormality that occurs when the lateral cartilages in the heel ossify. This can cause lameness.

*Ringbone* is a condition in which the cartilage all around the foot is ossified. Ringbone shows as a hard enlargement at the junction of bony hoof and hair areas.

*Bog spavin* is a soft swelling on the inner, anterior aspect of the hock.

*Bone spavin* is a bony enlargement on the inner aspect of the hock. Both bog and bone spavin arise when stresses are applied to horses that have improperly constructed hocks.

A *thoroughpin* is an enlargement between the large tendon (tendon of Achilles) of the hock and the fleshy portion of the hind leg.

*Capped hock* is a hard swelling at the point of the hock.

*Curb* is a hard swelling at the bottom-rear of the hock.

*Fistula* is a running sore on the withers.

*Poll evil* is a running sore on the poll of the head. These running sores develop after the head is bruised.

Several physiological abnormalities are known in horses. Some are due to inheritance. Others are due to faulty nutrition and management. An example of an inherited physiological abnormality in horses is *hemolytic icterus.* This condition is caused by a dominant antigen located on the red blood cells. Horses do not develop antibodies to their own antigens but they do develop antibodies to the antigens of other individuals. If a stallion that is *RR* (*R* denotes antigen production) is mated to a mare that is *rr* (*r* denotes no antigen production), the foal is *Rr.* As this foal develops, it produces an antigen that may cross the extra-embryonic membranes and enter the circulation of the mare, who then produces antibodies in response to this antigen. After two or three matings of the *RR* stallion to the same *rr* mare, the mare will have produced a high titer (amount) of antibodies. This situation is very similar to the "Rh" situation in humans. One major difference between the mare and the human female is that the antigen or the antibodies must cross

several maternal and placental cell layers in the mare. As a result, the antigen crosses these membranes and causes antibodies to be produced in the mare, but antibodies, which are larger molecules, do not enter the circulation of the foal. The foal is born normal, but the antibodies in the mother's milk can harm the foal. Because the gut wall of a newborn foal is quite porous, the antibodies in the mother's milk are absorbed from the gut into the bloodstream. The antibodies react with the red blood cells, causing the red blood cells to clump and be destroyed.

If a foal becomes ill from consuming milk that contains a high titer of antibodies, the only way to save its life is by blood withdrawal and transfusion such that all the afflicted blood is flushed from the foal. Withdrawal and transfusion are extremely expensive and are done only with horses of high value.

One can determine if a mare has developed a high titer of antibodies by testing her blood against the blood of an *RR* or *Rr* individual. If a mare has a high titer of antibodies, her foal will assuredly be harmed by consuming her milk. The foal can be "grafted" onto another mare (allowed to nurse from another mare) or given a milk replacer for a period of time. If the mare is milked to stimulate her to continue producing milk, her foal can be given back to her after a few weeks because the mare's titer will decrease and the foal's gut wall will become more impervious to antibodies.

Another condition that leads to death of the foal is a lack of iodine in the nutrition of the pregnant mare. If the fetus receives no iodine from the mare, it cannot produce thyroxine. The lack of thyroxine in the circulation of the fetus allows the anterior pituitary to produce large quantities of thyrotropic hormone. This hormone stimulates the development of the thyroid in the foal and results in the development of a goiter. A foal that is born with a goiter dies because a proper iodine-thyroxine balance cannot be established. Giving the foal iodine stimulates the body to produce an excessive amount of thyroxine; not providing iodine leaves the body lacking in thyroxine.

One can prevent goiter due to iodine deficiency by providing pregnant mares with iodized salt. Although goiter develops only in areas where iodine is naturally deficient, a general recommendation is to provide iodized salt to pregnant mares regardless of the area in which one operates.

## Gaits of Horses

The major gaits of horses, along with their modifications, are as follows:

1. *Walk* is a four-beat gait in which each of the four feet strikes the ground separately from the others.
2. *Trot* is a diagonal two-beat gait in which the right front and left rear feet hit the ground in unison, and the left front and right rear feet hit the ground in unison. The horse travels straight without weaving sideways when trotting.
3. *Pace* is a lateral two-beat gait in which the right front and rear feet hit the ground in unison and the left front and rear feet hit the ground in unison. There is a swaying from right to left when the horse paces.

4. *Gallop* is a three-beat gait. The hind feet hit the ground in unison. Both front feet hit the ground separately and at a different time than the hind feet.
5. *Canter* is a slow gallop.
6. *Rack* is a snappy four-beat gait in which the joints of the legs are highly flexed.
7. *Foxtrot* is a rhythmic trot.

## Abnormalities of Travel by Horses

A horse that toes out with its front feet tends to swing its feet inward when its legs are in action. Swinging the feet inward can cause the striding foot to strike the supporting leg so that interference to forward movement results. A horse that toes in tends to swing its front feet outward, giving a paddling action.

Some horses overreach with the hind leg and catch the heel of the front foot with the toe of the hind foot. This is called *forging.* It can cause the horse to stumble or fall. Some horses have a nervous condition, called *stringhalt,* in which the foot is picked up normally but is put down with an abrupt jerk due to a sudden impulse. A horse may dislocate the hind leg at the patella joint (joint at the flank). As a result, the horse drags the dislocated leg, because it cannot control its action. Setting the horse on its haunches by a sudden backward jerk on the bridle can snap the joint back into place.

## Determining the Age of a Horse by Its Teeth

One can estimate the age of a horse by its teeth (Figures 28-5, 28-6, and 28-7). A foal at 6 to 10 months of age has 24 "baby," or "milk," teeth—12 incisors and 12 molars. The incisors include three pairs of upper and three pairs of lower incisors.

Chewing causes the incisors to become worn. The wearing starts with the middle pair and continues laterally. At 1 year of age, the center incisors show wear; at 1.5 years, the intermediates show wear; and at 2 years, the outer, or lateral, incisors show wear. At 2.5 years, shedding of the baby teeth starts. The center incisors are shed first. Thus, at 2.5 years, the center incisors become permanent teeth; at 4 years, the intermediates are shed; at 5 years, the outer, or lateral, incisors are shed and replaced by permanent teeth.

A horse at 5 years of age is said to have a "full" mouth, because all the teeth are permanent. At 6 years, the center incisors show wear; at 7 years, the intermediates show wear; and at 8 years, the outer, or lateral, incisors show wear. Wearing is shown by a change from a deep groove to a rounded dental cup on the grinding surface of a tooth.

## Donkeys, Mules, and Hinnies

Mules and hinnies have been used as draft animals (for pulling heavy loads), in mining and farming operations, and as pack animals. When mules were needed for heavy loads, it was important to breed mammoth jacks to mares of one of the draft breeds. The crossing of smaller jacks with mares of medium size produced mules that were useful in mining and farming operations.

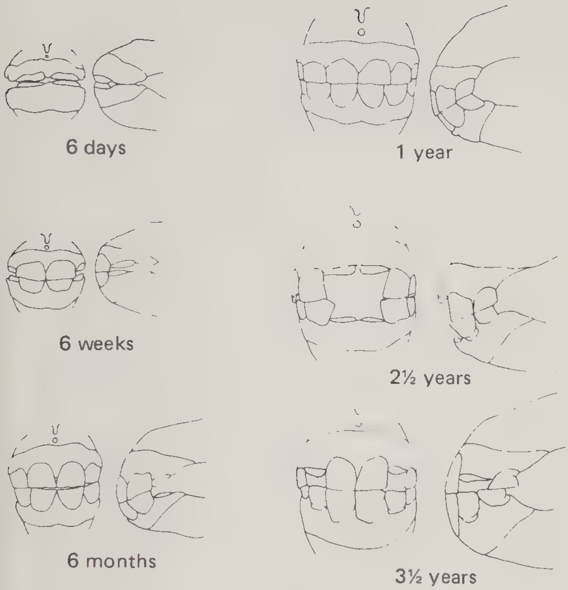



**FIGURE 28-5.** *Front and side views of the teeth of the horse from 6 days to 3.5 years of age. The young horse has a full set of "baby," or "milk," teeth by 6 months of age. It starts shedding the baby teeth and developing permanent teeth at 2.5 years of age. From Bone, J. D.* Animal Anatomy and Physiology, *4th ed., Corvallis: Oregon State University Book Stores. Copyright © 1975.*

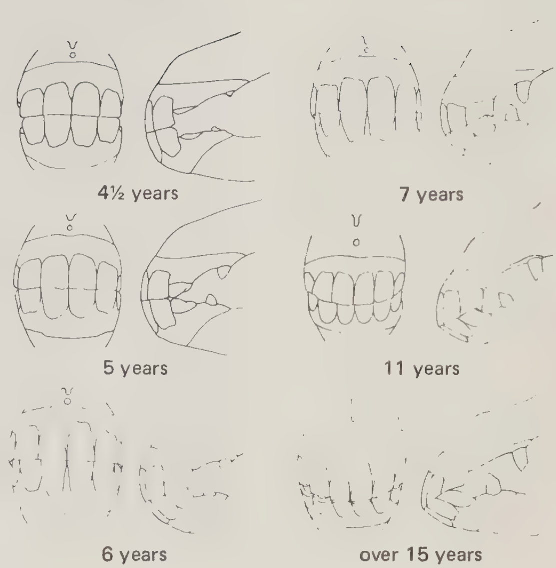



**FIGURE 28-6.** *Front and side views of the teeth of the horse from 4.5 to 15 years of age. The horse's mouth changes in shape as it becomes older such that the front teeth protrude somewhat forward. From Bone, J. F.* Animal Anatomy and Physiology, 4th ed., *Corvallis: Oregon State University Book Stores. Copyright © 1975.*

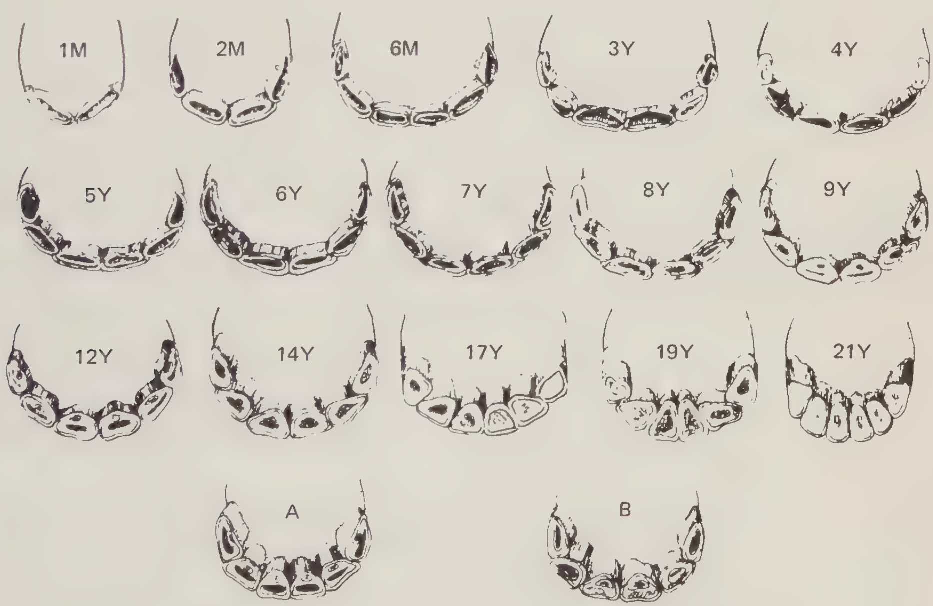



**FIGURE 28-7.** *Table surfaces of the lower incisors of the horse from 1 month to 21 years of age. From Bone, J. F.* Animal Anatomy and Physiology, *4th ed. Corvallis: Oregon State University Book Stores. Copyright © 1975.*

Donkeys, mules, and hinnies have some characteristics that make them more useful than horses for certain purposes. They are sure-footed; therefore, they make ideal pack animals for moving loads over rough areas. They are rugged and can endure abuse. In addition, they have the characteristic of taking care of themselves. For example, a mule that gets a leg caught in a barbed wire fence brays for someone to come to its rescue, whereas a horse might become excited and damage itself severely in an attempt to become free. Mules do not gorge themselves when grain feeds are before them; consequently, they do not normally founder (overeat).

Donkeys, mules, and hinnies do not respond to the wishes or commands of humans as readily as horses. They are often quite contrary.

Recently, there has been a movement to use small donkeys (burros) for pets for children. Small mules from crosses between male burros and mare ponies have also been in demand as children's pets.

The heavy use of mechanical equipment such as trucks, tractors, bulldozers, and automobiles has greatly reduced the need for mules as draft animals. Some are still used in logging operations and as pack animals, but mule production is not important in the United States. Most people prefer horses for pleasure animals because they respond to commands more readily than mules.

## Study Questions and Suggestions

1. For the American Quarter Horse, Thoroughbred, Tennessee Walking Horse, and Welsh, give their approximate height and the use that is made of each.
2. Define or explain the following terms:

| | |
|---|---|
| a. walk | f. ringbone |
| b. trot | g. thoroughpin |
| c. bog spavin | h. bone spavin |
| d. pace | i. sickle hocks |
| e. curb | j. interference |

3. a. If a horse toes in, will its legs tend to paddle or to interfere?
   b. What do we call the striking of the heel of the front foot with the toe of the hind foot when a horse travels?
   c. When a pregnant mare has a deficiency of iodine, what happens to the foal? How can this condition be prevented?
   d. Explain why some foals develop hemolytic icterus. How can one prevent the development of this disease?
   e. What are three important characteristics that horses should possess to make them most useful as pleasure horses?

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## Controlling Diseases and Parasites

Sanitation is of vital importance in controlling parasites of horses. A horse that is to be introduced into the herd should be isolated for a month prior to being run with the other horses. Any disease the animal may have been exposed to prior to the isolation period is thus given time to express itself. Keeping the stable clean and grooming the horse regularly contribute greatly to the welfare of the horse.

Horse manure is an excellent medium for microorganisms that cause *tetanus.* Horses should be given shots to prevent tetanus, which can develop if an injury allows tetanus-causing microorganisms to invade through the skin. Usually two shots are given to establish immunity, after which a booster shot is given each year. Because the same microorganisms that cause tetanus in horses also affect humans, those who work with horses should also have tetanus shots.

*Strangles,* also known as *distemper,* is a bacterial disease that affects the upper respiratory tract and associated lymph glands. High fever, nasal discharge, and swollen lymph glands suggest strangles. This disease is spread by contamination of feed and water. One must isolate replacement horses and provide clean water and feed. A strangles bacterin is available, but postvaccinal reactions limit its use to stables and ranches where the disease is endemic.

Brood mares are subject to many infectious agents which invade the uterus and cause abortion; examples include *Salmonella* and *Streptococcus* bacteria and the viruses of *rhinopneumonitis* and *arteritis.* Should abortion occur, obtain professional help to determine the specific cause and plan to prevent the problem in the future.

*Sleeping sickness,* or equine *encephalomyelitis,* is caused by virus infections that affect the brain of the horse. Different types, such as the

eastern and western types, are known. Encephalomyelitis is transmitted by such vectors as mosquitoes. It can also be spread by horses rubbing noses together. This disease is also transmissable to humans. Vaccination against the disease consists of two intradermal injections spaced a week to 10 days apart. These injections should be given in April. The vaccination insures immunity for only 6 months; therefore, one should repeat the injections each 6 months when the disease is prevalent.

*Influenza* is a common respiratory disease of horses. The virus that causes influenza is airborne, so exposure frequently occurs where horses congregate. The acute disease causes high fever and a severe cough when the horse is exercised. Rest and good nursing care for 3 weeks are suggested. Severe aftereffects are not common when complete rest is provided. Those horse owners who plan for shows should vaccinate for influenza each spring. Two injections are required the first year, with one annual booster thereafter.

Horses can become infested with internal and external parasites. Control of internal parasites consists of rotating horses from one pasture to another, spreading manure from stables on land that horses do not graze, and treating infested animals.

*Pinworms* develop in the colon and rectum from eggs that are swallowed as the horse eats contaminated feed or drinks contaminated water. They irritate the anus, which causes the horse to rub the base of its tail against objects even to the point of wearing off the hair and causing skin abrasions. Pinworms are controlled by oral administration of such chemicals as piperazine, Trichlorfon, and Thiabendazole, or by mixing Dichlorvos in the feed.

The term *bots* refers to the maggot stage of the bot fly. The female bot fly lays eggs on the hairs on the throat, front legs, and belly of the horse. The irritation of the bot fly causes the horse to lick itself. The eggs are then attached to the tongue and lips of the horse, where they hatch into larvae that burrow into the tissues. The larvae later migrate down the throat and attach to the lining of the stomach, where they remain for about 6 months and cause serious damage. Trichlorfon or carbon disulfide given orally, or Dichlorvos mixed with the feed, are used as treatments. Adult *strongyles* (bloodworms) are firmly attached to the walls of the large intestine. The adult female lays eggs that pass out with the feces. After the eggs hatch, the larvae climb blades of grass where they are swallowed by horses that are grazing. The larvae migrate to various organs and arteries where severe damage results. Blood clots form where arteries are damaged. Clots can break loose and plug an artery. Treatment of bloodworms consists of phenothiazine or Dichlorvos mixed with the feed or phenothiazine-piperazine mixture administered orally.

Adult *Ascaris* worms are located in the small intestine of the horse. The adult female produces large numbers of eggs which pass out with the feces. The eggs become infective; they are swallowed when the horse picks them up while grazing. The eggs hatch in the stomach and small intestine and the larvae migrate into the bloodstream and are carried to the liver and lungs. The small larvae are coughed up from the lungs and swallowed. When they reach the small intestine, they mature and produce eggs. The same chemicals used for the control of bots are effective in the control of ascarids.

# 30. Goats—What Are Their Contributions?

Goats do not make a large impact on the economy of the United States. In some parts of the world, however, goats are very important sources of human food. In the United States, goats are primarily important to those who raise them and to the increasing number of people who consume milk and meat from them.

There are three classes of domesticated goats: the dairy goat, which is used largely for the production of milk; the Angora goat, which is used mainly for the production of mohair and meat; and the Pygmy goat, which is used chiefly as a laboratory animal and pet.

The milk produced by dairy goats differs from cow milk. All of the carotene in goat milk is converted into vitamin A, and the type of curd formed when acids and enzymes act upon goat milk is different from the curd of cow milk. Goat milk is more readily digested and assimilated by some people because of these differences. The dairy goat is a desirable animal for providing milk for the family because it is small and less expensive to feed than a cow. Goats consume large quantities of browse that is unsuitable for cows.

## Characteristics of Breeds of Dairy Goats

The five major breeds of dairy goats registered in the United States are: Toggenburg, Saanan, French Alpine, Nubian, and American LaMancha. All are capable of high productivity. In fact, although the dairy goat and dairy cow are about equal in efficiency of feed conversion, the dairy goat produces much more milk in relation to its size than does the dairy cow.

**FIGURE 30-1**. *Four-year-old Tina Van Geest and people of all ages like goats because they are such affectionate animals. In many parts of the world, milk goats provide much of the animal products for the nutrition of people. The dairy goat is an ideal animal for 4-H and FFA projects. Young people can learn responsibility by doing a project in which they work with goats as well as gain some knowledge about reproduction, nutrition, and lactation. Miss Van Geest is the author's foster granddaughter. Photograph by the author, assisted by Mrs. Eva Rappaport.*

**FIGURE 30-2**. *An ideal Toggenburg doe, Lotta Daisies Dorli M. Note the fore attachment of the udder and the well-placed teats. Courtesy of Mrs. Eva Rappaport.*

FIGURE 30-3. *A Saanen doe, Foolish Question. Courtesy of Nancy Lee Owen.*

The *Toggenburg* is medium in size, is vigorous, and produces much milk (Figure 30-2). The highest record of milk production for one lactation by a Toggenburg female is 5,750 lbs. Toggenburgs may vary in color from a light fawn to a dark chocolate with white or cream on the ears, face, and muzzle, and on the legs from the hocks and knees down. Light color is also found on the udder and between the hind legs extending up on each side of the tail.

Breed Specific Faults and Disqualifications are determined for each breed of goat by the appropriate breed association. Breed Specific Faults of the Toggenburg are:

1. Few small white spots—moderate fault in does (females), serious fault in bucks (males).
2. Roman nose—moderate to serious fault depending on degree.
3. Smaller than minimum height (26 in.) or minimum weight (120 lbs.)—moderate fault.

Disqualifications of the Toggenburg are:

1. Tricolor, piebald, or large white spot.
2. White stomach (except British).
3. Pendulous (drooping) ears.

The *Saanen* is a large breed, capable of producing much milk (Figure 30-3). The record milk production for one lactation by a Saanen female is 5,496 lbs. Color ranges from white to cream in Saanens.

Breed Specific Faults are:

1. Dark cream color, several small spots in hair—serious fault.
2. Roman nose—moderate to serious fault depending on degree.
3. Smaller than minimum height (30 in.) or minimum weight (135 lbs.)—moderate fault.

Disqualifications are:

1. Large dark spot.
2. Any color but white or cream.
3. Pendulous ears.

**FIGURE 30-4.** *A French Alpine doe, Lotta Daisies Danica M. Courtesy of Mrs. Eva Rappaport.*

The *French Alpine* is a large, somewhat rangy goat (Figure 30-4). French Alpines also produce much milk; the record for one lactation of a female is 4,826 lbs. Alpines are graceful and attractive, with an endless variety of colors and color patterns.

Breed Specific Faults are:

1. Brown and white ("Togg" markings)—moderate fault in does, serious fault in bucks.
2. Roman nose—moderate to serious fault depending on degree.
3. Smaller than minimum height (30 in.) or minimum weight (135 lbs.)—moderate fault.

The Disqualification in the French Alpine is pendulous ears.

The *Nubian* is a large, proud-looking goat that differs from other goats in having long, wide, pendulous ears (Figure 30-5). It is the only breed required to have a Roman nose. Nubians can be any color or have any color pattern. The record milk production for one lactation of a Nubian female is 4,420 lbs., which is lower than for the three breeds previously described. However, Nubian milk is distinctive for its high milk fat content.

Breed Specific Faults are:

1. Dished face—very serious fault; straight face—moderate fault.
2. Droopy (not pendulous) ears—serious fault.
3. Smaller than minimum height (30 in.) or minimum weight (135 lbs.)—moderate fault.

The Disqualification in the Nubian is upright ears.

The *American LaMancha* goat differs from the other breeds in either having no external ears ("gopher" ears) or extremely short ears ("cookie" ears). Earlessness is inherited as a trait of incomplete dominance—heterozygous individuals have short ears, and individuals that are homozygous for earlessness have no ears (Figure 30-6). Any color or

FIGURE 30-5. *A Nubian doe. Note the ear size and shape. Courtesy of Mr. Jeffrey M. Mitchell.*

FIGURE 30-6. *A La-Mancha doe, GCH Long Gone Shika M L-1938. Note the earless condition. This individual is homozygous for earlessness. Courtesy of Mesquite Dairy Goat Farm, Central Point, Oregon.*

combination of colors may be observed in this breed. Milk production is relatively low; the record for one lactation for a LaMancha female is 3,408 lbs. It should be pointed out that relatively few females of this breed have been tested officially. Therefore, this low record may not indicate the breed's true capacity.

Breed Specific Faults are:

1. Roman nose—moderate to serious fault depending on degree.

2. Smaller than minimum height (28 in.) or minimum weight (130 lbs.)—moderate fault.

Disqualifications are:

1. Anything other than gopher ears in bucks.
2. Ears other than true LaMancha type in does.

One should keep in mind that the high records for each of the breeds do not indicate that the breed averages are that high. The average for a breed may be estimated at 60% of the outstanding record for a female of that breed.

# 35. Careers in Animal Science

Fifty years ago farming was a way of life. Farms were generally small and much of the food needed by persons on farms was produced and consumed on the farm. A farmer did not need a large financial income to make a living. Farmers in the midwestern, eastern, southern, and parts of the western areas of the United States raised several species of farm animals. It was not unusual for a farmer to milk a few cows, grow and fatten some pigs, raise a few sheep, and produce eggs and fryers. Horses and mules were used as sources of power; farmers raised a few foals to replace those that were no longer useful. It did not take a large investment to start livestock farming; consequently, a career in animal agriculture at that time generally meant the actual production of livestock.

It was then (50 years ago) that changes were beginning. Trucks and tractors were replacing horses and mules. Because of the greater financial outlay when tractors and trucks were used, and because one person using a tractor could farm larger acreages than one using horses and mules, the size of farms was increasing and the number of farms was decreasing. The increase in size of farms was brought about by large financial investments in mechanized machinery.

One of the changes that took place as farm size increased was specialization. Thus, generalized farming in which many species of farm animals were raised was replaced by specialized farming in which there was only, for example, dairying, beef production, or swine production. In fact, specialization has proceeded to the point that beef producers may be cow-calf operators or feedlot operators.

Along with the increase in size of each farming unit and the specialization that has occurred, the financial outlay necessary for one

to operate an economic unit has increased greatly. Also, there has been a marked decrease in the number of farms. At present, about 5% of the population of the United States produces most of the food for the entire population of this country and, in addition, much of the grain that is used in world trade.

The small number of farms and the large financial outlay required for farming have markedly reduced the opportunity for a career in livestock raising. It is extremely difficult for a young person to secure financial backing needed for livestock farming. If a young person can obtain financing for livestock farming today, this person needs to be well trained in nutrition, breeding, management, economics, marketing, and sanitation. This person will likely not need to know all about all of the species because it is likely that only one species will be produced on a given farm.

The specialization that has occurred has been spectacular in the United States. For example, some broiler producers market a few thousand birds each week, some dairies milk more than 500 cows regularly, some beef producers care for more than 2,000 producing cows, and some swine operators farrow from 500 to 1,000 sows twice a year. The poultry industry has specialized to a greater extent than other livestock areas. The baby chicks needed for raising the hens that produce most of the eggs and the baby chicks needed for broiler (or fryer) production are supplied by about six large breeding units.

What are the career opportunities available for young people? The livestock industry is a large one and even though only a small percentage of the population in the United States is engaged in the production of livestock, many persons are employed to supply the needs of the animal scientist. The persons working in areas that supply the needs of the livestock producer are better able to do this if they are well versed in animal science.

## The Feed Industry

Much of the feed that is used by livestock producers is processed and formulated by the feed industry. Rations are often developed by computer programming but the information provided to the computer must be determined by someone who knows the nutritional requirements of the animals, and the palatability, composition, and relative costs of the feeds to be used. There are many opportunities in the feed industry for young people who are well trained in nutrition and who know something about livestock production. In addition to developing better rations or supplements for other feeds, there is a need for selling the feed to livestock producers. Success in providing feeds to the producer depends on having a feed that helps the producer raise more and better livestock at a cost that allows for some profit. The selling of a feed includes helping the farmer know what to feed for maximum production at the least cost, and therefore must be based on a sound knowledge of nutrition and economics.

## The Production Industry

It has been stated previously that it is difficult for a young person to obtain financing for livestock production. It is, however, not impossible.

There are opportunities to become part of the livestock production industry. One may work for a livestock operator and use part of the pay received to invest in the operation. After a few years of work, one may have sufficient interest in the operation to finance the purchase of the remaining interest in the enterprise.

When one is financially able to own and operate a livestock operation, success will depend upon knowledge of livestock and economics and personal ability to make sound decisions. Knowledge of livestock includes a thorough understanding of reproduction, sanitation, and disease prevention. One also needs to understand economics and marketing to assist in making decisions as to when to expand, when and where to market, and how far to extend one's indebtedness.

## Livestock Marketing

Many persons who are well trained in animal science are needed in the marketing of livestock. In addition to knowing how to tell an animal's value from its appearance, one needs to know what the demand is for different classes and grades of livestock and what animals of each grade are worth. One must be well versed in marketing, but knowing animals of all species that come to the market is also essential. Someone who has had experience in live-animal appraisals will have an advantage in market employment. This knowledge enables one to sort animals according to the best use that can be made of them so that uniform lots can be offered for sale.

## Slaughterhouse Employment

Many persons are employed in slaughterhouse operations. A person who has good training in meats science can be particularly useful. Some slaughterhouses sell much of their meat as carcasses to chain stores such as Safeway without breaking the carcass into wholesale cuts. The buyer from a chain store usually wants the choice grade because this is the grade that is usually featured. The ability to grade carcasses is useful. A person trained in meat grading might be employed as a federal grader. The chain stores employ people to break the carcass meat into wholesale and retail cuts. One who is trained in meat cutting can earn good wages.

## Food Processing

All the meat going through slaughterhouses must be processed either into retail cuts or into some type of processed meat. At the present time, much of the meat is prepackaged into "pan-ready" servings. Much labor goes into boning and trimming and making cuts of serving size, after which the meat is packaged in clear cellophane wrap. There are opportunities for working in this area if one has a good knowledge of meats.

Some meat is ground and sold as ground meat or it may be mixed with other substances to provide a meat dish. Some finely ground meat is used in the preparation of canned baby foods. Some meat is prepared and canned as food for pet dogs and cats. There is an active, ongoing program in the development of more nutritious and palatable meat preparations. One who is highly trained in nutrition and meats science can make important contributions in this area.

## Laboratory (Pharmaceutical) Supplies

The livestock producer and the veterinarian who looks after the health of the herd rely on large laboratories for a supply of vaccines, antibiotics, disinfectants, hormones, insecticides, and antihelmintics. A person who has sound training in biology and animal science can be useful to such large laboratories. Drugs and vaccines must be tested thoroughly before they can be released for use. They must be effective for what they are intended but not hazardous to humans. Those persons involved in developing and testing these materials are extremely important to the livestock industry. The training necessary for employment in such activities is rigorous, but the type of work is satisfying and pays well.

In addition to the development and testing of drugs and vaccines, people are employed in sales of pharmaceuticals. One should be familiar with problems the producer faces and laws relative to how products may be sold, and be able to sell.

## Equipment Manufacturing

Most of the equipment made for handling livestock is designed by engineers. However, someone who has a knowledge of livestock can be of great assistance in helping engineers design equipment. It would be best if engineers who design livestock equipment would obtain good livestock training. Another alternative is for a few persons trained in animal science to be competent in engineering. The combination of knowledge would lead to better designs.

## Financing

Most livestock operators are in need of financing. There are opportunities for persons who know animal science to work for financial institutions such as banks, federal and state loaning agencies, and savings and loan organizations. One trained in animal science can help determine the amount of financing that a farmer needs, the likelihood that the obligations incurred can be met, and, most important, whether or not the anticipated venture is economically sound. In addition to helping the farmer arrange for financing, a person trained in animal science can provide advice that will help the farmer be more efficient.

## Large Livestock Operations

Some owners of large-scale livestock operations employ highly trained nutritionists, physiologists, geneticists, and veterinarians. The poultry breeding establishments that supply most of the baby chicks for producers and the artificial insemination establishments are examples. The poultry breeding organizations are few in number (there are about six or eight of them) but they employ geneticists, nutritionists, and physiologists who have a good background in animal and poultry science. The artificial insemination organizations employ highly trained geneticists to evaluate potential sires to be put in the program. They also employ many technicians for doing artificial insemination and pregnancy testing. Persons trained in animal science who have good training

either in genetics or in reproduction physiology are important personnel in any artificial insemination organization.

## Research

Livestock producers need all the help they can obtain in finding ways to increase the effectiveness of their operation. Research scientists at federal and state research centers are constantly investigating possibilities of increasing rate and efficiency of production, lowering costs of production, and increasing desirability of the meat or other products that are being produced. If one is interested in being a research scientist, it is necessary that rigorous training at the Ph.D. level be obtained.

A young person in college who hopes to do graduate work in order to become a research scientist should become well trained in chemistry, biology, physics, and mathematics as well as in animal science. Research in the areas of nutrition, genetics, physiology, and meats requires well-trained persons. This is a highly rewarding field. The research worker creates new knowledge and applies this knowledge to livestock production. Such findings contribute greatly both to the producer and to the consumer. Research done in the past has made it possible for the consumer to have the best food we know of at an affordable cost.

## Teaching

Good teachers are always in demand. One of the attributes of a good teacher is knowledge of the subject being taught. Many persons are employed in teaching in high school, in community and state colleges, in large universities, and in extension programs throughout the nation. Extension programs for adults and youths are not held in the normal classroom—they are held in the larger classroom of the farm. The vocational agricultural programs in high schools need persons trained in all aspects of agriculture of which animal science is a part. Community and state colleges need teachers of animal science. Larger universities employ highly trained animal scientists who teach undergraduate and graduate courses and do research.

## Livestock-Related Fields

Some students combine training in animal science with some other area. For example, one may combine animal science with journalism and become an editor of a livestock journal. One may combine livestock training with training in photography and become a livestock photographer. One may combine animal science and communications training and become a livestock advertiser. Or one may combine animal science and business training and go into agribusiness. There are many combinations in which animal science training is useful. Livestock auctioneering is an example in which one may use a trade school and university training in good combination.

## The Dairy Industry

The dairy industry is now composed of three units, each of which is a specialty in itself. These units of the dairy industry are (1) production,

(2) processing, and (3) distribution. There are opportunities for students who are well trained in dairy procedures to be caretakers for young calves. One who has the training and is willing to give young calves the attention required can keep the calves in good health; consequently, such a person is in strong demand.

Like calves, the cow herd must be properly fed and given proper care. One must know how to work with cows as well as what and when to feed them. Persons to do the milking are always needed. All dairy cows and goats are under the serious strain of high production; therefore, the milker needs to know a great deal about the dairy animals so that any abnormal situations or conditions can be noted and corrected or treated. Time is important in the milking operation; therefore, milkers must be alert. The udders of good dairy cows or goats can be ruined by improper use of the milking machine.

The processing of milk is not only a specialty in itself, but the preparation of different products is often a highly specialized operation. For example, some persons may be employed to make cheeses, others to manufacture ice cream, and others may make butter. Employment in dairy processing not only requires training in dairying but also some specialized training in dairy manufacturing. In addition, persons employed in dairy processing are usually given a short training period in the plant in which they are employed.

In the field of distribution of dairy products one may find employment in delivering milk and other products to homes or in delivering dairy products to stores where the products are sold to customers. One may also be employed in the sale of dairy products.

Persons trained in dairying who are also well versed in economics and marketing are needed. Analyses of which dairy products are in greatest demand, where the demands are the greatest for each product, and how best to make an attractive offering of the products are all important. Advertising is important in the sale of dairy products. One who is trained in advertising and who has a good background in dairying can make a real contribution in this area.

## The Poultry Industry

The poultry industry is highly specialized. In addition, there is a great deal of vertical intergradation in this industry. Large feed processors often contract with a broiler producer so that the broiler producer does not have a large investment in feed until the birds are marketed, at which time the income from the birds pays for the feed and the labor of the producer. Opportunities for employment in the poultry industry are also available to persons trained in poultry husbandry who care for young birds or laying hens, operators of incubators, feed salespersons, and equipment salespersons.

Some chickens and most turkeys are artificially inseminated. One who is well trained in artificial insemination and in working with poultry is needed to do this work.

The processing of poultry requires trained personnel. Slaughtering, cleaning, cutting the carcasses into cuts, packaging, and other such operations require a great deal of labor. Grading, sizing, and packaging of eggs in cartons for sale also requires labor.

There are places for a few highly trained geneticists, physiologists, and nutritionists, who also have poultry training, in the large establishments that produce eggs or baby chicks for use in the production of broilers or laying hens. These persons must be highly trained at the Ph.D. level because the future of the establishment depends upon such persons. Although the training for such positions is rigorous, the compensation is good and there is satisfaction in such work.

One should bear in mind that much of the discussion in the early portion of this chapter, though dealing largely with other animals, is applicable to both the dairy and the poultry industries.

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# Glossary

**abortion:** The expulsion or delivery of a fetus before it is able to survive. Young that are born dead prior to term are considered abortions. Live young born prior to term are premature.

**absorption:** The passage of liquid and digested (soluble) food across the gut wall.

**accessory organs:** The seminal vesicles, prostate, and Cowper's glands in the male. These glands add their secretions to the sperm to form semen. They are less essential than testicles.

**achondroplasia:** A defect in the formation of cartilage at the epiphyses of long bones, producing a form of dwarfism.

**acute:** Severe but of short duration.

**additive genes:** Genes that show no dominance. The effect of each gene is additive.

**agnathia:** The congenital absence of a jaw, usually the lower jaw.

**agonistic behavior:** Combat, or fighting, behavior, which includes defense (submission), offense (aggression), escape, and passiveness.

**AI:** Abbreviation for artificial insemination.

**alleles:** Genes occupying corresponding loci in homologous chromosomes that affect the same hereditary trait but in different ways.

**allelomimetic behavior:** Doing the same thing.

**amino acid:** An organic acid in which one or more of the hydrogen atoms has been replaced by the amino group ($—NH_2$). Amino acids are the building blocks in the formation of proteins.

**ampulla:** The dilated or enlarged upper portion of the vas deferens in bulls, bucks, and rams, where sperm are stored for sudden release at ejaculation.

**amputated:** Having a limb or other parts cut off. The inherited condition called amputated is a genetic failure of development of the lower portions of the legs and mandibles.

**anabolic:** A constructive, or "building up," process.

**anatomy:** The science of the structure of the animal body and the relation of its parts.

**androgen:** A male sex hormone, such as testosterone.

**anemia:** A condition in which the blood is deficient in quantity of red blood cells or in its hemoglobin content.

**antagglutin:** A conjugated protein constituent of semen that prevents agglutination of the sperm cells. It originates chiefly in the prostate.

**anterior:** Situated in front of, or toward the forward part of, a point of reference. Toward the head end of an animal.

**antibiotic:** A product produced by living organisms, such as yeast, which destroys or inhibits the growth of other organisms, especially bacteria.

**antibody:** A specific protein substance formed by and in an animal as a reaction to the presence of an antigen. Antibodies may cause flocculation, lysis, or inactivation of antigens.

**antigen:** A substance which, when introduced into the blood or tissues, causes the formation of antibodies. Antigens may be toxins or native proteins.

**antihormone:** An antibodylike substance developed when protein hormones are injected into an animal over a period of time. Antihormones inactivate hormones.

**antiseptic:** A chemical substance that prevents growth and development of microorganisms.

**apparent digestible energy:** Gross energy minus energy in feces.

**artificial insemination:** The introduction of semen into the reproductive tract (usually the cervix or uterus) of the female by a technician.

**artificial vagina:** A device used to collect semen from a male while he mounts in a normal manner to copulate. The male ejaculates into this device, which simulates the vagina of the female in pressure, temperature, and sensation to the penis.

**assimilation:** The process of transforming food into living tissue.

**atrophic rhinitis:** The wasting away (rotting) of tissues of the nasal sinuses.

**autosome:** Any chromosome other than the *X* and *Y* (sex) chromosomes.

**A.V.:** Abbreviation for artificial vagina.

**baby beef:** Young slaughter beef animals that weigh approximately 1,000 lbs. and are well finished at about a year of age.

**backcross:** (1) The mating of a crossbred ($F_1$) animal back to one of the parental breeds. (2) The mating of a heterozygote back to one of the parental homozygotes.

**balanced ration:** The daily food that provides all required nutrients in proper proportion for normal health, growth, reproduction, lactation, maintenance, or work.

**barrow:** A male swine that was castrated prior to reaching puberty.

**basal metabolism:** The chemical changes that occur in an animal's body when the animal is in a thermoneutral environment, resting, and in a postabsorp-

tive state. It is usually determined by measuring oxygen consumption and carbon dioxide production.

**beef:** The meat from cattle (bovine species) other than calves (the meat from calves is called veal).

**behavior:** The reaction of an animal to internal and external stimuli, which is an attempt by the animal to adjust or adapt to the situation.

**blemish:** Any defect or injury that mars the appearance of, but does not impair the usefulness of, an animal.

**bloat:** A marked distension of the rumen and reticulum with gases. It is seen as an enlargement of the left side of the abdomen.

**boar:** A male swine of breeding age. This term sometimes denotes a male pig, which is called a boar pig.

**bog spavin:** A soft enlargement of the anterior, inner aspect of the hock.

**bolus:** (1) Regurgitated food. (2) A large pill for dosing animals.

**bone spavin:** A bony (hard) enlargement of the inner aspect of the hock.

**bovine:** Pertaining to, or derived from, ox, cow, or hiefer. Hollow-horned animals.

**breech:** The buttocks. A breech presentation at birth is one in which the rear portion of the fetus is presented first.

**British thermal unit:** The quantity of heat required to raise the temperature of 1 lb. of water 1°F at or near 39.2°F.

**broiler:** A young chicken of either sex (usually 9 to 12 weeks of age) that is tender meated and has smooth-textured skin and flexible breastbone cartilage.

**broodiness:** The desire of a female bird to sit on eggs (incubate).

**browse:** Woody or brushy plants. Livestock feed on tender shoots or twigs.

**buck:** A male sheep, goat, or rabbit. This term usually denotes animals of breeding age.

**buffer:** A substance in a fluid that lessens the change in hydrogen ion concentration when either acids or alkalis are added.

**bulbourethral (Cowper's) gland:** An accessory gland of the male that secretes a fluid which constitutes a portion of the semen.

**bull:** A bovine male. The term usually denotes animals of breeding age.

**buttermilk:** The fluid remaining after butter has been made from cream and removed. By use of bacteria, cultured buttermilk is also produced from milk.

**Caesarean operation:** The delivery of a baby animal by an incision through the abdominal and uterine walls.

**calf:** A young male or female bovine animal.

**calorie:** The amount of heat required to raise the temperature of 1 g of water from 15°C to 16°C.

**cancer eye:** A malignant tumor composed chiefly of epithelial cells in the eye.

**cannibalism:** The eating by animals of other animals of the same kind.

**canter:** A slow, easy gallop.

**capped hocks:** Hocks that have hard growths that cover, or "cap," their points.

**carbohydrates:** Any foods, including starches, sugars, celluloses, and gums, that are broken down to simple sugars through digestion.

**carcass merit:** The value of a carcass for consumption.

**carnivorous:** Subsisting or feeding on animal tissues.

**carotene:** The orange pigment found in carrots, leafy plants, yellow corn, and other feeds, which can be broken down to form two molecules of vitamin A.

**casein:** The major protein of milk.

**castrate:** (1) To remove the testicles or the ovaries. (2) An animal that has had its testicles or ovaries removed.

**catabolic:** A term referring to a destructive process, such as the destruction of molecules in the animal's body.

**cataract:** An opacity of the crystalline eye lens or its capsule.

**cecum:** The first part of the large intestine.

**cervix:** The portion of the female reproductive tract between the vagina and the uterus. It is usually sealed by thick mucus except when the female is in estrus or delivering young.

**chick:** A young chicken of either sex.

**chorion:** The outermost envelope of the prenatal organism which serves as a protective and nutritive covering.

**chromosome:** A rodlike or stringlike body found in the nucleus of the cell that is darkly stained by chrome dyes.

**chyme:** The thick, liquid mixture of food that passes from the stomach to the small intestine.

**chymotrypsin:** A milk-digesting enzyme contained in the pancreas.

**clitoris:** An organ in females inside the ventral part of the vulva which is homologous to the penis in the male. It is highly sensory.

**clutch:** Eggs layed by a hen on consecutive days.

**cob-roller:** A term used to describe short, thick, fat pigs. The pig's belly is so near the ground that the pig is said to be able to roll a corn cob as it walks.

**coccidiosis:** A morbid state caused by the presence of organisms called coccidia, which belong to a class of sporozoans.

**cockerel:** A young male chicken from about 10 weeks to 8 months of age.

**coefficient of inbreeding:** A coefficient showing the relationship of the parents of an individual to one another. It is a measure of the amount of homozygosity created in the offspring by mating related parent animals.

**colic:** Acute abdominal pain.

**colostrum:** The first milk given by a female following delivery of her young. It is high in antibodies that give the young protection from invading microorganisms.

**colt:** A young male of the horse or donkey species.

**combining ability:** The ability of animals of a population or line to produce superior or inferior offspring when combined with other populations or lines.

**compensatory growth:** Increased growth rate in response to previous austerity that an animal has recently experienced.

**concentrate:** A feed that is high in energy, low in fiber content, and highly digestible.

**condition:** (1) The state of health and well-being of an animal. (2) The amount of finish that an animal carries.

**conditioning:** (1) The treatment of internal and external parasites of animals. (2) Immunization against certain diseases prior to sending animals to the feedlot.

**conformation:** The physical form of an animal; its shape and arrangement of parts.

**contagious:** Transmissible by contact.

**continuous variation:** Variation among individuals for a trait that shows no discrete classes; the variation ranges from one extreme to the other.

**contracted heels:** A condition in which the heels of a horse are pulled in so that expansion of the heel when the foot strikes the ground cannot occur.

**convection:** The cooling or warming of an animal by air currents.

**copulation:** The act of mating.

**corpus luteum:** A yellowish body in the mammalian ovary. The cells that were follicular cells develop into the corpus luteum, which secrets progesterone. It becomes yellow in color from the yellow lipids that are in the cells.

**cow:** A sexually mature female bovine animal.

**cow hocks:** A condition in which the hocks are close together but the feet stand apart.

**creep:** An enclosure surrounded by a fence through which large animals cannot pass, in which food for young animals is placed.

**crimp:** The waves, or kinks, in a wool fiber.

**crossbreeding:** A term generally used to mean the crossing of two breeds of farm animals. It sometime denotes the crossing of lines, breeds, or species of animals.

**cull:** To eliminate from breeding or to prevent from leaving genes in the population.

**curb:** A hard swelling that occurs just below the point of the hock.

**curd:** Coagulated milk.

**cutting chute:** A narrow chute that allows animals to go through in single file with gates such that animals can be directed into pens along the side of the chute.

**dam:** The female parent.

**deamination:** The removal of the amino group from an amino acid.

**defecation:** The voiding of feces.

**delayed implantation:** The delayed attachment of a fertilized egg to the wall of the uterus after fertilization takes place.

**digestibility:** The quality of being digestible. If a high percentage of a given food taken into the digestive tract is absorbed into the body, that food is said to have high digestibility.

**digestion:** The reduction in particle size of food so that the food becomes soluble and can pass across the gut wall into the vascular or lymph system.

**dihybrid:** A double heterozygote, *AaBb*.

**dihybrid cross:** A cross involving two pairs of alleles.

**diploid:** Having the normal, paired chromosomes of somatic tissue as produced by the doubling of the primary chromosomes of the germ cells at fertilization.

**disease:** Any deviation from a normal state of health.

**disinfectant:** A chemical that destroys disease-producing microorganisms or parasites.

**dock:** (1) To cut off the tail. (2) The remaining portion of the tail of a sheep that has been docked.

**doe:** A female goat or rabbit.

**dominance:** A situation in which one gene of an allelic pair prevents the phenotypic expression of the other member of the allelic pair.

**dominant gene:** A gene that overpowers and prevents the expression of its recessive allele when the two alleles are present in a heterozygous individual.

**dorsal:** Pertaining to the back, or toward the back.

**dressing percentage:** The percentage of the live animal that becomes the carcass at slaughter. It is determined by subtracting the losses due to removal of blood, hide, and intestines from live-animal weight, dividing that quantity by live-animal weight, and multiplying by 100.

**dry cow:** A cow that is not presently producing milk.

**dung:** The feces (manure) of farm animals.

**dwarfism:** The state of being abnormally undersized. Two kinds of dwarfs are recognized; one is proportionate and the other is disproportionate.

**ear canker:** A crusty orange material in the ear of rabbits resulting from infestation by ear mites.

**ejaculation:** A discharge of semen from the male.

**ejaculator:** An electric instrument used for causing a male animal to ejaculate. It is inserted into the rectum and discharges an electrical impulse that causes ejaculation. It requires careful operation as to voltage and frequency of stimulus.

**embryo:** The young animal from the time the egg and sperm unite (fertilization) until the organ systems are formed.

**endocrine gland:** A ductless gland that secretes a hormone into the bloodstream.

**energy:** The force, or power, that is used to drive a wide variety of systems. It can be used as motive power in animals, but most of it is used as chemical energy to drive reactions necessary to convert feed into animal products and to keep the animal warm.

**entropion:** Turned-in eyelids.

**environment:** The sum total of all external conditions that affect the well-being and performance of an animal.

**enzyme:** A complex protein produced by living cells that causes changes in other substances in the body without being changed itself and without becoming a part of the product.

**epididymis:** The long, coiled tubule leading from the testis to the vas deferens.

**epiphysis:** A piece of bone separated from a long bone in early life by cartilage, which later becomes part of the larger bone.

**epistatic:** A term designating a gene that interacts with other genes with which it is not allelic.

**epithelial defects:** Improperly formed skin, particularly of the extremities, that allows fluid to exude from the body.

**eruction:** The elimination of gas by belching.

**essential nutrient:** A nutrient that cannot by synthesized by the body, but must be supplied in the ration.

**estrogen:** Any hormone (including estradiol, estriol, and estrone) that causes the female to come physiologically into heat and to be receptive to the male. Estrogens are produced by the follicle of the ovary and by the placenta.

**estrous:** An adjective meaning "heat," which modifies such words as "cycle." The estrous cycle is the heat cycle, or time from one heat to the next. The Americanized term is **estrual** (see **estrus**).

**estrus:** The period of mating activity in the female mammal. The time when the female has a strong sexual urge. It is also called heat.

**ewe:** A sexually mature female sheep. A ewe lamb is a female sheep prior to sexual maturity.

**family selection:** Selection based on performance of a family.

**farrow:** To deliver, or give birth to, pigs.

**fat:** Adipose tissue.

**feather picking:** The picking of feathers from one bird by another.

**fecal energy:** The energy that is voided through the feces.

**feed bunk:** A manger for providing feed, usually hay or silage, to cattle, sheep, goats, or horses.

**feed conditions:** The conditions under which animals are being fed; sometimes used to designate the level of feeding.

**feed efficiency:** (1) The amount of feed required to produce a unit of gain in weight; for poultry, this term can also denote the amount of feed required to produce a given quantity of eggs. (2) The amount of gain made per unit of feed.

**feeder calf:** A calf that is purchased to go directly into the feedlot.

**feedlot:** A lot in which animals on a finishing ration are kept.

**felting:** The intermingling of wool fibers to produce woolen cloth.

**female sterility:** Inherited sterility that is limited to females in cattle.

**fertility:** The capacity to initiate, sustain, and support reproduction. With reference to poultry, the term typically refers to the percentage of eggs which, when incubated, show some degree of embryonic development.

**fertilization:** The process in which a sperm unites with an egg to produce a zygote.

**fetus:** A young organism in the uterus from the time that the organ systems have been formed until it is born.

**filly:** A young female horse.

**finish:** The degree of fatness of an animal.

**fistula:** A running sore at the top of the withers of a horse, resulting from a bruise followed by invasion of microorganisms.

**fleece:** The wool from all parts of a sheep.

**fleshing:** (1) A term that refers to the physical condition of an animal or to the amount of fatness that is possesses. (2) Removing all excess flesh, fat, and grease from a pelt.

**flushing:** Having females fed to gain in condition for stimulating greater rates of ovulation and conception.

**fly strike:** An infestation with large numbers of maggots hatched from eggs laid by blowflies.

**foal:** A young male or female horse.

**foal heat:** Heat that occurs in a mare 5 to 7 days following the birth of her foal.

**follicle:** A blisterlike, fluid-filled sac in the ovary that contains the egg.

**follicle-stimulating hormone:** A hormone produced and released by the anterior pituitary that stimulates the development of the follicle in the ovary.

**forb:** Weedy or broad-leaf plants, as contrasted to grasses, that serve as pasture for animals.

**forging:** The striking of the heel of the front foot with the toe of the hind foot by a horse in action.

**founder:** To overeat to the point that illness results. Foundering results in laminitis, a condition in which the hoof grows unusually rapidly.

**freshen:** To give birth to young and initiate milk production. This term is usually used with reference to dairy cattle.

**fused teats:** Teats that are close together or, often, joined together on one side.

**gallop:** A three-beat gait in which each of the two front feet and both of the hind feet strike the ground at different times.

**gametes:** Male and female reproductive cells. The sperm and the egg.

**gametogenesis:** The process by which sperm and eggs are produced.

**gelding:** A male horse that has been castrated.

**gene:** An active area in the chromosome that codes for a trait and determines how a trait will develop.

**general combining ability:** The ability of individuals of one line or population to combine favorably or unfavorably with individuals of several other lines or populations.

**genotype:** The genetic constitution, or makeup, of an individual. For any pair of alleles, three genotypes (*AA, Aa,* and *aa*) are possible.

**germ plasm:** The hereditary material (genes).

**gestation:** The time from breeding of a female until she gives birth to her young.

**gilt:** A young female swine prior to the time that she has produced her first litter.

**globulin:** A protein characterized by being insoluble in water and alcohol but soluble in a 0.5% to 1.0% solution of a neutral salt, from which solution it can be precipitated by heat.

**gonad:** The testicle of the male; the ovary of the female.

**grading up:** The continued use of purebred sires of the same breed in a grade herd or flock.

**gross energy:** The amount of heat, measured in calories, produced when a substance is completely oxidized. It does not reveal the amount of energy that an animal could derive from eating the substance.

**growing out:** Developing a young animal to a larger size.

**growth:** The increase in protein over its loss in the animal body. Growth occurs by increases in cell numbers, cell size, or both.

**habituation:** The gradual adaptation to a stimulus or to the environment.

**half-sib:** A half-brother or half-sister. Animals that are half-sibs usually have the same sire but different dams.

**hand mating:** Bringing a female to a male for service (breeding), after which she is removed from the area where the male is located.

**hank:** A measurement of the fineness of wool. A hank is 560 yds. of yarn. Fine wools spin more yarn that coarse wools; thus, the spinning count for fine wools is high.

**haploid:** One-half of the diploid number of chromosomes for a given species, as found in the germ cells.

**hatchability:** A term that indicates the percentage of a given number of eggs set from which viable young hatch, sometimes calculated specifically from the number of *fertile* eggs set.

**heat increment:** The increase in heat production following consumption of feed when an animal is in a thermoneutral environment. It includes additional heat generated in fermentation, digestion, and nutrient metabolism.

**heaves:** A respiratory defect in horses in which the animal has difficulty completing the exhalation of inhaled air.

**heifer:** A young female bovine cow prior to the time that she has produced her first calf.

**hemophilia:** An inherited condition characterized by delayed clotting of the blood and consequent difficulty in checking hemorrhage.

**hen:** An adult female domestic fowl, such as a chicken or a turkey.

**herbivorous:** Subsisting or feeding on plants.

**heritability:** The portion of phenotypic variation that is accounted for by additive gene action.

**hernia:** The protrusion of some of the intestine through an opening in the body wall (also commonly called rupture). Two types, umbilical and scrotal, occur in farm animals.

**heterosis:** The amount by which the $F_1$ generation exceeds the $P_1$ generation for a certain trait (also called hybrid vigor). The animal breeder usually speaks of the amount of superiority the crossbred has over the straightbreds.

**heterozygote:** A heterozygous individual.

**heterozygous:** A term designating an individual that possesses unlike genes for a particular trait.

**hinny:** The offspring that results from crossing a stallion with a female donkey (jenny).

**hobble:** To tie the front legs of an animal together, or to tie the hind legs to a rope run between the front legs and over the shoulder. An animal is hobbled to prevent it from kicking.

**homeotherm:** A "warm-blooded" animal. An animal that maintains its characteristic body temperature even though environmental temperature varies.

**homologous:** Corresponding in type of structure and derived from a common primitive origin.

**homologous chromosomes:** Chromosomes having the same size and shape that contain genes affecting the same characters. Homologous chromosomes occur in pairs in typical diploid cells.

**homozygote:** A homozygous individual.

**homozygous:** A term designating an individual whose genes for a particular trait are alike.

**hormone:** A chemical substance secreted by a ductless gland. This substance is usually carried by the bloodstream to other places in the body where it has its specific effect.

**hutch:** A pen for small animals such as rabbits.

**hybrid:** (1) A heterozygous individual. (2) An offspring of genetically unlike parents. Some animal breeders use "hybrid" to refer to an individual that results from a cross of two lines, two breeds, or two species.

**hybrid vigor:** The added vigor of crossbreds over their straightbred parents (see **heterosis**).

**hydrocephalus:** A condition characterized by an abnormal increase in the amount of cerebral fluid, accompanied by dilation of the cerebral ventricles.

**hypoglycemia:** A significant decrease in blood sugar level.

**hypothalamus:** A portion of the brain found in the floor of the third ventricle. It regulates body temperature and has other functions.

**immunity:** The ability of an animal to resist or overcome an infection to which most members of its species are susceptible.

**implantation:** (1) The embedding of an embryo in the lining of the uterus. (2) The transfer of, or the grafting of, parts in an animal.

**inbreeding:** The mating of individuals who are more closely related than the average individuals in a population. Inbreeding increases homozygosity in the population but it does not change gene frequency.

**incubation period:** The time that elapses from the time an egg is placed into an incubator until the young is hatched.

**index:** (1) An overall merit rating of an animal. (2) A method of predicting the milk-producing ability that a bull will transmit to his daughters.

**inheritance:** The transmission of genes from parents to offspring.

**instinct:** Inborn behavior.

**intelligence:** The ability to learn to adjust successfully to situations.

**interference:** The striking of the supporting leg by the foot of the striding leg by a horse in action.

**interstitial cells:** The cells between the seminiferous tubules of the testicle that produce testosterone.

**intravenous:** Within the vein. An intravenous injection is an injection into a vein.

**inverted nipple:** A condition in which the teat or nipple turns into the gland canal instead of protruding.

**jenny:** The female donkey.

**ked:** An external parasite that affects sheep. Although commonly called "sheep tick," it is actually a wingless fly.

**kemp:** Coarse, hairlike fibers in wool.

**ketosis:** A condition (also called acetonemia) which is characterized by high concentration of ketone bodies in the body tissues and fluids.

**kilocalorie (kcal, Kcal):** An amount of heat equal to 1,000 calories (see **calorie**). Also called Calorie.

**kindle:** Deliver, or give birth to, rabbits.

**kit:** The young of mink.



**lactation:** The secretion and production of milk.

**lactose:** Milk sugar. When digested, it is broken down into one molecule of glucose and one of galactose.

**lamb:** (1) A young male or female sheep, usually an individual less than 10 months of age. (2) To deliver, or give birth to, a lamb.

**lambing jug:** A small pen in which a ewe is put for lambing. It is also used for containing the ewe and her lamb until the lamb is strong enough to run with other ewes and lambs.

**lateral:** Of, at, from, or toward the side.

**lean cutability:** The amount of trimmed lean retail cuts that can be obtained from a carcass, usually expressed as a percentage.

**legume:** Any plant of the family Leguminosae, such as pea, bean, alfalfa, and clover.

**lethal gene:** A gene (or genes) that causes death of the young prior to, or shortly following, birth. Delayed lethal genes are those that cause death of the individual later in life. Partial lethals cause a condition to exist which may result in death if certain conditions are present.

**line crossing:** The crossing of inbred lines.

**linkage:** The tendency of certain traits or genes to be inherited together rather than independently, because the genes are located on the same chromosome.

**lipid:** An organic substance that is soluble in alcohol or ether but insoluble in water.

**litter:** The young produced by such multiparous females as mink, swine, and rabbits. The young in a litter are called litter mates.

**luteinizing hormone:** A protein hormone, produced and released by the anterior pituitary, which stimulates the formation and retention of the corpus luteum.

**macroclimate:** The large, general climate in which an animal exists.

**macromineral:** A mineral that is needed in the diet in relatively large amounts.

**maggot:** The larva of a fly.

**maintenance:** A condition in which the body is maintained without an increase or decrease in body weight and with no production or work being done.

**mane:** The long hair on the top of the neck of a horse.

**marbling:** The distribution of fat in muscular tissue.

**mare:** A sexually developed female horse.

**market class:** Animals grouped according to the use to which they will be put, such as slaughter, feeder, or stocker.

**market grade:** Animals grouped within a market class according to their value.

**masticate:** To chew food.

**mastitis:** An inflammation of the mammary gland.

**mastitis-metritis-agalactia (MMA) complex:** A disease of swine in which the mammary glands and uterus are inflamed, and there is absence or failure of milk secretion.

**masturbation:** Ejaculation by a male without involving a female.

**meiosis:** A special type of cell nuclear division that is undergone in the production of gametes (sperm in the male, ova in the female). As a result of meiosis, each gamete carries half the number of chromosomes of a typical body cell in that species.

**metabolism:** (1) The sum total of chemical changes in the body, including the "building up" and "breaking down" processes. (2) The transformation by which energy is made available for body uses.

**metabolizable energy:** Gross energy minus the sum of energy in feces, gaseous products of digestion, and energy in urine.

**metric ton:** One thousand kilograms, equal to 2204.6 lbs.

**microclimate:** A small, special climate within a macroclimate created by the use of such devices as shelters, heat lamps, and bedding.

**micromineral:** A mineral that is needed in the diet in relatively small amounts. The quantity needed is so small that such a mineral is often called a trace mineral.

**milk fat:** The fat in milk.

**milk letdown:** The squeezing of milk out of the udder tissue into the gland and teat cisterns.

**milk replacer:** A dry, commercially prepared feed that has a composition similar to milk. Water is added to it to provide a milklike feed for young, particularly calves and pigs.

**milk solids:** The solids in milk, including fat, protein, minerals, and lactose.

**mineral:** An inorganic substance required in the diet. Minerals are classified as either macrominerals or microminerals.

**minimum culling level:** A selection method in which an animal must meet minimum standards for each trait desired in order to qualify for being retained for breeding purposes.

**mitosis:** A process in which a cell divides to produce two daughter cells, each of which contains the same chromosome complement as the mother cell from which they came.

**modifying genes:** Genes that modify the expression of other genes.

**mohair:** The fibers produced from the skins of Angora rabbits and goats.

**monogastric:** Having only one stomach or only one compartment in the stomach. Examples are swine, mink, and rabbits.

**monohybrid:** An individual that is heterozygous (*Aa*) for one pair of genes.

**monoparous:** A term designating animals that usually produce only one offspring at each pregnancy. Horses and cattle are monoparous.

**moon blindness:** Periodic blindness that occurs in horses.

**mule:** The hybrid that is produced by mating a male donkey with a female horse.

**multiparous:** A term that designates animals that usually produce several young at each pregnancy. Swine, rabbits, and mink are multiparous.

**mutation:** A change in a gene.

**mutton:** The meat from mature sheep.

**navel:** The area where the umbilical cord was formerly attached to the body of the offspring.

**needle teeth:** Sharp upper and lower teeth at the corners of the mouth of baby pigs.

**net energy:** Metabolizable energy minus heat increment. The energy available to the animal for maintenance and production.

**nicking:** The way in which certain lines, strains, or breeds perform when mated

together. When outstanding offspring result, the parents are said to have nicked well.

**nutrient:** (1) A substance that nourishes the metabolic processes of the body. (2) The end product of digestion.

**obesity:** An excessive accumulation of fat in the body.

**omnivorous:** Feeding on both animal and vegetable substances.

**on full feed:** A term that refers to animals that are receiving all the feed they will consume.

**oogenesis:** The process by which eggs, or ova, are produced.

**otolith:** An ear stone; one of the small calcereous masses within the membranous vestibule, near the termination of the auditory nerve.

**outbreeding:** The process of continuously mating females of the herd to unrelated males of the same breed.

**outcrossing:** The mating of an individual to another in the same breed which is not related to it.

**ovary:** The female reproductive gland in which the eggs are formed and progesterone and estrogenic hormones are produced.

**overdominance:** A type of gene expression in which the heterozygote is superior to either of the homozygotes.

**overeating disease:** A toxic condition caused by the presence of undigested carbohydrates in the intestine, which stimulates harmful bacteria to multiply. When the bacteria die, they release toxins.

**oviduct:** A duct leading from the ovary to the horn of the uterus.

**ovulation:** The shedding, or release, of the egg from the follicle of the ovary.

**pace:** A lateral two-beat gait in which the right rear and front feet hit the ground at one time and the left rear and front feet strike the ground at another time.

**paddling:** The outward swinging of the front feet of a horse that toes in.

**paralysis:** The loss of normal power of motion in some part or organ of the body.

**parasite:** An organism that lives a part of its life cycle in or on, and at the expense of, another organism. Parasites of farm animals live at the expense of the farm animals.

**parental:** Pertaining to, or derived from, parents.

**pasteurization:** The process of heating milk to 161°F and holding it at that temperature for 15 seconds to destroy pathogenic microorganisms.

**pasture rotation:** The rotation of animals from one pasture to another so that some pasture areas have no livestock on them in certain periods.

**pathogenic:** Disease-causing.

**pedigree:** The record of the ancestry of an animal.

**pelt:** The natural, whole skin covering, including the wool, hair, or fur.

**pendulous:** Hanging loosely.

**penis:** The male organ of copulation. It serves both as a channel for passage of urine from the bladder as an extension of the urethra, and as a copulatory organ through which sperm are deposited into the female reproductive tract.

**performance test:** The evaluation of an animal by its own performance.

**peristalsis:** Wavelike muscular contractions of tubes, such as the intestines and the oviduct, which enable the tube to propel material in its lumen.

**persistency of lay:** The length of time that a bird lays eggs before molting or before completely ceasing to lay.

**phenotype:** The characteristics of an animal that can be seen and/or measured. For example, the presence or absence of horns, the color, or the weight of an animal.

**physiology:** The science that pertains to the functions of organs, organ systems, or the entire animal.

**pig:** A young swine.

**poikilotherm:** A "cold-blooded" animal. An animal whose body temperature varies with that of the environment.

**poll:** The back part of the head of an animal.

**polled:** Naturally or genetically hornless.

**poll evil:** An abscess behind the ears of a horse.

**pork:** The meat from swine.

**postdigestive fermentation:** (See **postgastric fermentation.**)

**posterior:** Situated behind, or toward the rear of, a point of reference. Toward the rear end of an animal.

**postgastric fermentation:** The fermentation of feed that occurs in the cecum, behind the area where digestion has occurred.

**poult:** A young turkey prior to the time that its sex can be determined.

**predigestive fermentation:** (See **pregastric fermentation.**)

**pregastric fermentation:** Fermentation that occurs in the rumen of ruminant animals. It occurs before feed passes into the portion of the digestive tract in which digestion actually occurs.

**prenatal:** Prior to being born. Before birth.

**probe:** A device used to measure backfat thickness in pigs.

**production testing:** An evaluation of an animal based on its production record.

**production trait:** Any trait of a farm animal that contributes to the production of a product for which the animal is used.

**progeny testing:** An evaluation of an animal on the basis of the performance of its offspring.

**progesterone:** A hormone produced by the corpus luteum that stimulates progestational proliferation in the uterus of the female.

**prolapse:** Abnormal protrusion of part of an organ.

**prolonged gestation:** An obvious extension of the length of pregnancy.

**prostate:** A gland of the male reproductive tract that is located just back of the bladder. It secretes a fluid that becomes a part of semen at ejaculation.

**protein:** A substance made up of amino acids that contains approximately 16% nitrogen (based on molecular weight).

**protoplasm:** The only known form of matter in which life is manifested.

**puberty:** The age at which the reproductive organs become functionally operative.

**pullet:** A female chicken from about 10 weeks to 8 months of age.

**pullorum disease:** A disease of poultry caused by the bacterium *Salmonella pullorum* that can be transmitted from hen to offspring through the egg. It usually causes high mortality in birds younger than 10 days of age.

**purebred:** An animal that meets the standard of a recognized breed and whose ancestors are registered in the herd book of that breed.

**ram:** A male sheep that is sexually mature.

**rate of lay:** (1) The number of eggs laid in a standard time interval. (2) The percentage of eggs produced in a variable time interval.

**reactor:** An animal that reacts when tested to determine if it has a disease, either by swelling when skin tests are made or by agglutination when blood tests are made.

**realized heritability:** The portion obtained of what is reached for in selection.

**reasoning:** The ability of an animal to respond correctly to a stimulus the first time that the animal encounters a new situation.

**recessive gene:** A gene that has its phenotype masked by its dominant allele when the two genes are present together in an individual.

**reciprocal recurrent selection:** The selection of breeding animals in two populations based on the performance of their offspring after animals from two populations are crossed.

**recurrent selection:** Selection for general combining ability by selecting males that sire outstanding offspring when mated to females from varying genetic backgrounds.

**regurgitate:** To cast up undigested food to the mouth as is done by ruminants.

**reinforcement:** A reward for making the proper response to a stimulus or condition.

**replicate:** To duplicate, or make another exactly like, the original.

**reproduction:** The production of live, normal offspring.

**ringbone:** An ossification of the lateral cartilage of the foot of a horse all around the foot.

**roughage:** A feed that is high in fiber, low in digestible nutrients, and low in energy. Such feeds as hay, straw, silage, and pasture are examples.

**ruminant:** A mammal whose stomach has four parts (rumen, reticulum, omasum, and abomasum).

**rumination:** The regurgitation of undigested food and chewing of it for a second time, after which it is again swallowed.

**scours:** A diarrhea of watery feces.

**scrotum:** A pouch which contains the testicles. It is also a thermoregulatory organ that contracts when cold and relaxes when warm, thus tending to keep the testicles at a lower temperature than that of the body.

**scurvy:** A deficiency disease in humans which causes spongy gums and loose teeth. It is caused by a lack of vitamin C.

**selection:** Differentially reproducing what one wants in a herd or flock.

**selection differential:** The difference between records of animals selected and records of the population from which the selected animals were chosen.

**semen:** The fluid containing the sperm that is ejaculated by the male. Secretions from the seminal vesicles, the prostate gland, the Cowper's glands, and the urethral glands provide most of the fluid.

**seminal vesicles:** Accessory sex glands of the male that provide a portion of the fluid of semen.

**seminiferous tubules:** Minute tubules in the testicles in which sperm are produced.

**settle:** To become pregnant or to make pregnant.

**sex-influenced trait:** A trait in which the sex of the animal influences the phenotype of the heterozygote. For example, in blackish cattle, testosterone causes male heterozygotes (*Bsbs*) to be dark.

**sex-limited trait:** A trait that is limited to one sex. The production of eggs or milk, for example, is limited to females.

**sex-linked trait:** A trait that is controlled by genes located on one of the types of sex chromosomes, either on the *X* chromosome (*X*-linked) or on the *Y* chromosome (*Y*-linked).

**sialoprotein:** The chief, or characteristic, component of the viscous, whitish, sometimes rubbery secretion of the bulbourethral gland; it plays an important part in forming the gel in the semen of the boar and stallion.

**sib testing:** A method of selection in which a male is selected on the basis of the performance of his sisters or a female is selected on the basis of the performance of her brothers.

**sickle hocks:** Hocks which have too much set, causing the hind feet to be too far forward and too far under the animal.

**side bones:** Ossification of the lateral cartilages of the foot of a horse.

**sigmoid flexure:** The S-curve in the penis of boars, rams, bucks, and bulls.

**shoat:** A young swine after it is weaned, until it reaches market size.

**short prime:** An inherited condition in which the vertebral column is shortened but the bones of the legs are not.

**silage:** Forage, corn fodder, or sorghum preserved by fermentation that produces acids similar to the acids that are used to make pickled foods for people.

**soilage:** Green forage that is cut and brought to animals as food.

**solids-non-fat:** Total solids minus fat. It includes protein, lactose, and minerals.

**somatotropin:** The growth hormone from the anterior pituitary that stimulates nitrogen retention and growth.

**sow:** A female swine that is sexually mature.

**spasm:** A sudden, violent, involuntary contraction of a muscle or a group of muscles.

**spay:** To surgically remove the ovaries from a female.

**specific combining ability:** The ability of a line or population to combine superiorly or inferiorly with other lines or populations.

**spermatid:** The haploid germ cell prior to spermiogenesis.

**spermatogenesis:** The process by which spermatids that carry half as many chromosomes as a typical body cell of the individual are produced in the seminiferous tubules of the testicle.

**spermatozoa:** Male germ cells.

**spermiogenesis:** The process by which the spermatid loses most of its cytoplasm and develops a tail to become a mature sperm.

**spinning count:** The number of hanks of yarn that can be spun from a pound of clean wool. One method of evaluating fineness of wool.

**splints:** Small, hard bumps under the skin in the cannon (shin) bones caused by incorrect healing of small chips of bone.

**stags:** Castrated male sheep, cattle, goats, or swine that have reached sexual maturity prior to castration.

**stallion:** A sexually mature male horse.

**steer:** A castrated bovine male that was castrated early in life before puberty.

**sterility:** A condition in which an individual is incapable of producing young. Barren.

**stocker calf:** A calf that is purchased to go back to a farm or ranch to grow before it goes to the feedlot or to develop it as a breeding animal.

**stovers:** Dried stalks and leaves, but not the grain portion, of corn, cane, or milo.

**stringhalt:** A sudden and extreme flexion of the back of a horse, producing a jerking motion of the hind leg in walking.

**suckling gain:** The gain that a young animal makes from birth until it is weaned.

**subcutaneous:** Situated beneath, or occurring beneath, the skin. A subcutaneous injection is an injection made under the skin.

**sweeny:** Atrophy of the muscles of the shoulder of a horse.

**tags:** The wool at the rear of a sheep that is coated with dung.

**T.D.N.:** Total digestible nutrients; it includes the total amounts of digestible protein, nitrogen-free extract, fiber, and fat (multiplied by 2.25) all summed together.

**teaser ram:** A ram made incapable of impregnating a ewe by vasectomy or by use of an apron to prevent copulation, which is used to find ewes in heat.

**tendon contracture:** An inherited condition in which the tendons are pulled rigidly. It causes death of newborn cattle.

**testicle:** The male sex gland that produces sperm and testosterone.

**testis:** (See **testicle.**)

**testosterone:** The male sex hormone that stimulates the accessory sex glands, causes the male sex drive, and causes the development of masculine characteristics.

**tetanus:** An acute infectious disease caused by toxin elaborated by the bacterium *Clostridium tetani,* in which tonic spasms of some of the voluntary muscles occur.

**thoroughpin:** A hard swelling that is located between the Achilles tendon and the bone of the hock joint.

**titer:** A quantity of a substance required to produce a reaction with a given volume of another substance.

**tom:** A male turkey.

**trichinosis:** A disease caused by infestation by the trichina worm. It is contracted by eating insufficiently cooked pork that contains cysts of this worm.

**trot:** A diagonal two-beat gait in which the right front and left rear feet strike the ground in unison, and the left front and right rear feet strike the ground in unison.

**twitch:** To tightly squeeze the upper lip of a horse by means of a small rope that is twisted.

**type:** (1) The physical conformation of an animal. (2) All those physical attributes that contribute to the value of an animal for a specific purpose.

**udder:** The encased group of mammary glands of mammals. Each mammary gland is provided with a nipple or teat.

**umbilical cord:** A cord through which arteries and veins travel from the fetus to and from the placenta, respectively. This cord is broken when the young are born.

**unsoundness:** Any defect or injury that interferes with the usefulness of a horse.

**urinary energy:** The energy that is lost through the urine.

**uterus:** That portion of the female reproductive tract where the young develops during pregnancy.

**vagina:** The copulatory portion of the female's reproductive tract. The vestibule portion of the vagina also serves for passage of urine during urination. The vagina also serves as a canal through which young pass when born.

**vas deferens:** Ducts that carry sperm from the epididymis to the urethra.

**vasectomy:** The removal of a portion of the vas deferens. As a result, sperm is prevented from traveling from the testis to become part of the semen.

**veal:** The meat from very young cattle.

**ventral:** Underneath, or toward the abdomen of, an animal.

**vermifuge:** A chemical substance given to animals to kill internal parasitic worms.

**vitamin:** An organic catalyst, or component thereof, which facilitates specific and necessary functions.

**vulva:** The external genitalia of a female mammal.

**walk:** A four-beat gait of a horse in which each foot strikes the ground at a time different from each of the other three feet.

**warble:** The larval stage of the heel fly that burrows out through the hide of cattle in springtime.

**weaner calf:** A calf at or shortly following the time that it is weaned.

**weaning:** Taking a young animal from its dam so that it can no longer suckle from the dam.

**wether:** A male sheep or goat castrated before puberty.

**white heifer disease:** A condition in which the hymen is persistent and/or the cervix is incomplete. The horns of the uterus become distended with fluid.

**winter pause:** The tendency for fowl not to lay eggs for short periods in wintertime.

**wool:** The fibers that grow from the skin of sheep.

**woolens:** Cloth made from short wool fibers that are intermingled in the making of the cloth by carding.

**worsteds:** Cloth made from wool that is long enough to comb and spin into yarn. The finish of worsteds is harder than woolens and worsted clothes also hold a press better.



**yearling:** A sheep, goat, or beef or dairy bovine that is 12 to 18 months of age.

**zone of thermoneutrality:** The environmental temperature (about 65°F) at which heat production and heat elimination are approximately equal for most farm animals.

**zygote:** (1) A cell formed by the union of two gametes. (2) An individual from the time of fertilization until death.

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